The Invention in claims 1, 3, 5-7, 9, 10, 12, 14-16, 18, 19, 21, 23-25 and 27 are rejected under 35 U.S.C. § 102 as being anticipated by U.S. Patent No. 6,711,470 to Hartenstein et al, as in the previous office action

My Attorney at the time, Mr. Nevin Shaffer, Jr. P.A., inadvertently omitted several words from our August 19, 2005 filling. He can be contacted to verify this issue (850) 934-4134. Applicant understands how omitting these words could easily confuse the Examiner and his Supervisor. I apologize for any confusion this has caused. The omitted words have been added and claims 1, 10 and 19 have been amended, in pertinent part "a) at least one pressure sensor per floor <u>on at least two of said multiple floors</u>; b) a connection means for connecting <u>to the</u> pressure sensors; and c) attaching an analyzer to said pressure sensors for receiving input from said pressure sensors and comparing at least one pressure reading <u>from one floor</u> with <u>another</u> pressure reading <u>from at least one of the other multiple floors of said building</u> and for providing sensor data output", to further separate his invention from Hartenstein, and ALL others. These amendments represent clarifications and do add further limitations to the respective claims and the claims that are dependent on them.

I hereby TOTALLY disagree with the Examiner and his Supervisor's assertion that "the prior art controls pressure". Applicant respectfully replies that Hartenstein **NEVER** claims to compare the contaminants, temperature, humidity or pressure of "one individual floor with the contaminants, temperature, humidity or pressure of another floor", as I claim. **NOR** does **ANY** other patent in the World, claim to "compare at least one pressure reading from one floor with another pressure reading from at least one of the other multiple floors of said building", as I claim. The Whitmore patent number 4,606,228 does not claim this, it discloses a

"pressure transducer" which may, or may not, be used to solve a "temperature" problem associated with the myth of "warm air rising" in multiple floor buildings. So, how could Hartenstein, or **ANY** other patent be used to keep this patent at hand, from being granted?

Hartenstein ONLY mentions pressure sensors FOUR TIMES, and then he NEVER says ANY THING about what he intends to do with the pressure data that he retrieves. Applicant fails to see EXACTLY how this limited use of pressure sensors by Hartenstein; or Whitmore's "pressure diaphragm" claims, could EVER be considered as establishing the "state-of-the-art" for an "**INTERNAL BUILDING PRESSURE APPARATUS AND METHOD**", as I claim, under the requirements of 35 U.S.C. § 102. I will COMPLETELY address the Whitmore patent, later in this filing

35 US.C. § 103 REJECTION

> Claims 4, 8, 13, 17, 22 and 26 are rejected under 35 U.S.C. § 103, second paragraph, as being unpatentable over U.S. Patent No. 6,711,470 to Hartenstein et al, as in the previous office action.

I am NOT attempting to patent the tool of "averaging". Many others before me have used it. I am just employing it as a tool, to improve my resolution The real truth is that my actual field experience has taught me that when I was operating a floor of a building at a "positive" pressure, it is BEST accomplished by ignoring all but the "lowest" (minimum) pressure reading (the one nearest to zero, or even below), from the floors involved,I would then ONLY use this "lowest" pressure reading to manipulate the building's HVAC system to achieve my "desired" goal on one of the floors involved.

I also discovered that this "lowest" pressure, CONSTANTLY, "moves" from one "particular floor" to another; and from one "particular portion of a floor", to another; and from one "particular wall of a floor", to another, and it could end up being within a wall cavity, within a floor cavity, within a ceiling cavity, or within some other interstitial space. Inversely, for "negative" pressure buildings I would simply use the "highest" (maximum) pressure reading (the one furtherest away from zero) I received, to manipulate the building's HVAC system. But I do not want to give up "averaging" as a tool when applying my ideas, It may just prove to be an invaluable "tool" in the future. NEITHER Hartenstein, NOR Whitmore, discloses using ANY pressure measurements/readings, for ANY of the above reasons, or purposes,So EXACTLY how do they, or ANY OTHER patent establish the "prior art" for the invention, I am claiming, per the guidelines of 35 U.S.C. § 103, second paragraph

This is the primary NON OBVIOUS reasoning behind using the words "a group including maximum pressure, minimum pressure and average pressure and pressure in-between maximum and minimum for a particular floor, a portion of a particular floor and the building as a whole". Plus, it is also the primary reasoning behind the NON OBVIOUS locations I list in my subject claims, for pressure sensor locations These are NEW, NOVEL and NON OBVIOUS reasons for my pressure sensor locations, and exactly which pressure reading I choose to use, to manipulate the HVAC system, and represent a dramatic advance in the "state of the art" in "internal building pressure measurement and control".

I hereby declare that I have NEVER seen, or even heard of ANYONE ELSE locating pressure sensors where I want to locate them, for the reasons

I am employing. Plus, I hereby declare that I have NEVER seen, or even heard of ANYONE ELSE choosing ANY pressure reading from "a group including maximum pressure, minimum pressure and average pressure and pressure in-between maximum and minimum for a particular floor, a portion of a particular floor and the building as a whole", as I claim Hartenstein NEVER discloses the above way to use his pressure readings, NOR does he disclose ANY reasons for the locations of his "pressure sensors", when he mentions them ONLY FOUR TIMES. So, EXACTLY how can Hartenstein, or ANY other patent in the World, be used to keep this patent at hand from being granted There is NOT another patent that discloses the above reasons, so the "subject matter as a whole" and even in the "minutia" of this patent at hand are NEW, NOVEL and NON-OBVIOUS, and should be granted. Applicant respectfully fails to see how can it be rejected under 35 U.S.C. § 103, second paragraph, in light of this argument.

STATUS OF THE CLAIMS

Claims 1, 3-10, 12-21 and 23-27 remain pending in this case. New claims 28-48 have been added, to further disclose the invention.

Claims 1, 10 and 19 have been amended, in pertinent part "a) at least one pressure sensor *per floor* <u>on at least two of said multiple floors</u>; b) connecting <u>to the</u> pressure sensors; and c) an analysis means connected to said pressure sensors for receiving input from said pressure sensors and comparing at least one pressure reading <u>from one floor</u> with <u>another</u> pressure reading <u>from at least one of the other multiple floors of said building</u> and for providing sensor data output". These amendments

represent clarifications and do add further limitations to the respective claims.

Claims 28-48 were added to this application to include ideas originally taught by the invention, and described on page 3, lines 16-21; page 4, lines 1-3; and page 14, lines 8-17, of the initial application.

APPLICANT'S RESPONSE TO EXAMINER'S "RESPONSE TO ARGUMENTS"

I hereby respectfully and TOTALLY disagree with the Examiner and his Supervisor's assertion that "pressure is dependant upon the differences in temperatures from one floor to the next, or from one room to the next". I can NOT imagine how the teachings of Jacques Charles on temperature and pressure, could possibly be used to disapprove the patent at hand. I personally can NOT find a SINGLE formula that will produce a significant pressure effect in light of the 6 to 15 temperature differences that occur within a building. Especially when humidity is controlled to 50%, as in a standard building. Perhaps you can enlighten me with the specific formulas you are referring to. I hereby assert that the pressure generated by the "buoyancy factors" of "warm air rising" is INSUFFICIENT to "move" air through "sealed" FIRE floors, or EVEN closed elevator doors.

Or, if by these words, you are suggesting that temperature requirement differences "from one floor to the next, or from one room to the next", which results in "different" amounts of air being introduced into these various areas, SOMEHOW, MYSTERIOUSLY leaves ALL of the different spaces involved, at a UNIFORM pressure. THEN I ALSO TOTALLY DISAGREE!! This Examiner and his Supervisor might just be operating under the prevalent MISCONCEPTION that the "internal" areas of buildings reside at

a UNIFORM pressure, NATURALLY, regardless of the number of floors involved. Or, your misconceptions of the problems associated with "internal" building pressure, have left you unable to see the Applicant's solution, as stated on page 2, lines 15-21, plus page 3, lines 1-6, along with the aforementioned added paragraphs, of my application. I humbly request that you reconsider the argument made in this filing.

As far as HVAC systems and standard temperature control systems leaving multiple floor buildings at a UNIFORM pressure, I have discovered this to be a TOTALLY INCORRECT assumption. The REAL truth is that putting air into the various floors of a multiple floor building, based solely on a temperature and/or humidity basis, will actually generate the very "errant pressure bubbles", that the Applicant has discovered within buildings through the application of his granted patents and is now attempting to correct, with the patent at hand. When you link these "errant pressure bubbles" with the SEVERE, "NEGATIVE", pressures of the upper floors, as described previously, contaminants, odors, humidity, gases, biologicals, viruses, bacteria, mold, mildew, diseases, flu and yes even temperatures, WILL "move" uncontrollably within the building, from floor to floor, and from a part of a floor to a part of another floor, in patterns that NO ONE could EVER predict, even with the MOST SOPHISTICATED mathematical models The ONLY way to overcome these pressure forces, is to "measure", "analyze" and "control" them, EXACTLY as I am claiming, ONE FLOOR AT A TIME. The "delay" involved with the SINGLE interior sensor employed by ASHRAE on multiple floor buildings, dooms their scheme to FAILURE.

How else did the sars virus get from the fourth floor to the eleventh floor of a 33 floor apartment building in Hong Kong? The virus "traveled" through a "wall chase", which is why I want to put pressure sensors in

cavities and other interstitial spaces of multiple floor buildings. I ask the question, "why didn't the virus precipitate out on one of the other 31 floors, than the eleventh"? It was because the eleventh floor had the lowest pressure in relationship to the fourth floor, due to an unpredictable "errant pressure bubble". I have seen this very occurrence in MANY multiply floor buildings, when I was diagnosing humidity problems. I have seen air and humidity move from the fifth floor of a building to the third floor, through an interior "wall chase", completely ignoring the fourth floor. Why, because the third floor had the lowest pressure in relationship to the fifth floor. Contaminants, odors, humidity, gases, biologicals, viruses, bacteria, mold, mildew, diseases, flu and temperatures, could have been moved by this "errant pressure bubble", JUST AS EASY. This is why I want to compare the pressures of non adjacent floors.

I hereby declare that I learned most of what I am teaching about "building pressure", through humidity research. It is almost impossible to "see" the minute pressure differences that I saw, when only taking "hand held" pressure readings. Yet, through the thousands of dewpoint readings that I took in buildings, I began to notice how humidity was being "uncontrollably" moved around within the building, including from floor to floor, and a portion of a floor to portion of another floor, by what I began to call, "errant pressure bubbles". I hereby declare that I personally owned approximately $12,000 worth of very sophisticated humidity and pressure test equipment, which I subsequently lost to hurricane IVAN, on September 15, 2004, along with the two year old work truck that housed them. The simple truth is, that a $2,000 dewpoint meter with a four foot long probe, gave me a $100,000,000 education on "internal building pressures", and taught me things that NO ONE, HAS EVER KNOWN BEFORE.

Through the above argument, the Applicant TOTALLY DISAGREES "that conventional buildings control pressure". Plus, Applicant TOTALLY DISAGREES that "the HVAC system then becomes a pressure regulator, as it maintains the temperature in various rooms of a building", for the SAME reasons. Applicant wants to make it VERY CLEAR that the opposite is TRUE. Conventional buildings DO NOT control pressure. NEITHER thermostats, NOR HVAC systems are, CURRENTLY, an adequate pressure regulator within multiple floor buildings. The simple FACT is, that NEITHER a standard HVAC system, NOR a standard building control system could EVER "control" the pressures on the separate floors of a building, WITHOUT the addition of Applicant's patent at hand, and/or the Applicant's other granted patents. The Examiner and his Supervisor are simply incorrect.An amusing fact is that the article supplied by the Examiner, and written by Mr. Lstiburek, TOTAL refutes this very assertion by the Examiner, "that conventional buildings control pressure".

The Applicant states respectfully that the Examiner has made TOTALLLY incorrect statements such as "conventional buildings control pressure, since pressure is dependant upon the differences in temperatures from one floor to the next. The applicant should note that the HVAC system then becomes a pressure regulator, as it maintains the temperature in various rooms of a building." I ask the simple question, "how does this temperature control or HVAC system 'measure' much less 'control/ regulate' the air that "infiltrates" and "exfiltrates" through the "skin" of the building", as described in the above argument? Applicant "googled" over fifty internet articles looking for one that is teaching what he is claiming. I did find the Whitmore patent number 4,606,228, but it does NOT claim what I claim, and I will address it later. Applicant now respectfully request that the Examiner and his Supervisor "google"

"building pressure and indoor air quality" and read several of those 634,000 articles. MOST of them refute the assertion by the Examiner and his Supervisor, that the "HVAC system then becomes a pressure regulator". If the HVAC system were such a **GOOD** pressure regulator, then there would NOT be so many buildings with pressure problems.

For the THIRD time I reply in detail. Webster's dictionary defines "regulate" as: (1a) "to govern or direct according to rule", (1b) "to bring under control of"; (2) "to bring order, method, or uniformity to"; (3) "regulate the pressure of a tire". Webster's describes "control" as, (1a) "to check, test or verify by evidence". Does this Examiner and his Supervisor actually believe that a thermostat truly "regulates" and/or "controls", "building pressure", per Webster's. HOW? Also, how does the thermostat "bring order, method or even uniformity" (Webster's number '2' "regulate" definition) to the pressure of a building, much less a specific floor of a multiple floor building, or to ANY part of the building, as I claim.

Especially when the Examiner's own words include "the change in temperature, which is controlled by the thermostat, **inadvertently changes** the pressure". Plus, I am EXTREMELY interested in this Examiner and his Supervisor explaining to me "EXACTLY how does the thermostat "measure and compare at least one pressure reading from one floor with another pressure reading from at least one of the other multiple floors of said building", as I claim? Additional, EXACTLY what "evidence" (Webster's number '1a' "control" definition) does the thermostat provide that the desired pressure has been achieved, as I claim, on a particular floor, a portion of a particular floor, or ANY WHERE in the building, for that matter?

I am not trying to simply "change" building pressure, as the

Examiner and his Supervisor are suggesting. "Change" as defined by Webster's is: (1a) "to make different in some particular"; (1b) "to make radically different; (1c) "to give a different position, course or direction". This sounds more like you are saying that the thermostat will make the pressure "different" on the various floors, which is EXACTY what I have discovered and the above mentioned 634,000 internet articles verify. It also sounds like a thermostat that **"inadvertently changes"** pressure, could NEVER "bring order, method, or uniformity to" (Webster's number '2' "regulate" definition) the pressure of the various floors of multiple floor buildings, by making them "different". Please clearly explain how you say the thermostat will ACCURATELY "control" or "regulate" the pressure of a floor, or the pressure ANYWHERE in the building, to a desired pressure, BASED on these definitions by Webster's. My invention at hand will ACCURATELY "control/regulate internal building pressure", as I claim. Another confusing and incorrect method employed by this Examiner, is the way you moved form the assertion of "control" and "regulator" to "change". Per the above Webster's definitions of these three words, please tell me how can you interchange them? Are you purposefully attempting to confuse a situation, that you should be attempting to bring clarity to?

Should we all now just "regulate" the pressure of our tires (Webster's number '3' "regulate" definition) by **"inadvertently changing"** the tire's pressure. Or should we use "temperature" as a way to "regulate" our tire pressure, as this Examiner and his Supervisor assert. I know we measure our tires when they are "cool", but in this context, "cool" is a "state", NOT a temperature. A lot more people will die on our highways, if we begin to implement the logic proposed by this Examiner and his Supervisor. NO, the way to "regulate" the pressure of our tires is the same way we have done

It for the past 100 years By using a tire "pressure" gauge (pressure sensor in my patent) to "measure" the "pressure" of a tire, then compare that pressure measurement to what is desired (the analyzer in my patent) and then "control/regulate" the "pressure" of the tire by adding or removing air (the controller and HVAC systems in my patent) and then "measuring" again and repeating the process until the "desired pressure is obtained" (the pressure sensor, analyzer, controller and HVAC system in my patent).

This is EXACTLY what I claim to do, per floor of a building, to measure internal building pressure with pressure sensors on at least two floors and compare the measurements with an analyzer and then "regulate/control internal building pressure" by adding or removing air using a controller and the HVAC system, and then repeat the process until the "desired internal building pressure is obtained", by using ALL of these components together. I have NEVER claimed any desire to just "change", or make the "internal pressure of a building" simply "different", as you are suggesting. Interestingly, Whitmore's scheme will ONLY make "pressures" of the various floors "different", and will NEVER "control/regulate" them, to produce a "desired pressure" as I claim.

This "desired pressure is obtained" through manipulation of the existing or new building HVAC/Mechanical system to add or remove air, from EACH floor involved, in NEW AND NOVEL WAYS. WITHOUT sacrificing space temperature or humidity control I have done EXACTLY this on separate projects with Johnson Controls and Honeywell Controls (two of the LARGEST Controls Contractors in America) and I can provide contact information with these Control Contractors and the Industrial Plants involved.Since NO ONE, including Whitmore and Hartenstein, are currently "controlling" the "floor to floor pressure relationship of buildings, based on

directly measuring their pressure relationship", as I claim. THERE IS NO PRIOR ART INVOLVED, so I SHOULD NOT BE MADE TO LIMIT MY PATENT AT HAND BY DETAILING THESE METHODS OF CONTROL as this Examiner and his Supervisor request. This is PRIORITY INFORMATION that the Applicant has spent valuable time and money to discover, and he should NOT be forced to reveal them in this patent application

I will say that it is TOTALLY IMPRACTICAL to "pump" air from one floor to another, in an attempt to solve the problem, as Whitmore alludes. This would simply cause as many problems as it solved, if not MORE. It would ADD another variable to an already "dynamic" situation and "slow" down the process into a FAILURE mode. Since the amount of "exfiltrated" air varies DRAMATICALLY with height, storms, how "leaky" the building is, wind turbulence caused by surrounding structures, etc..,the amount of air required to pressurize the building also varies DRAMATICALLY, SECOND BY SECOND. If I was to draw air from one floor and move it to another as Whitmore "theorizes", I know the other variables involved would leave the floors involved, at ANYTHING but the "desired pressure". To "pump" air out of the already NEGATIVE upper floors, will ONLY exacerbate an already bad situation. Plus, Whitmore's scheme would end up "pumping" contaminants, odors, humidity, gases, biologicals, viruses, bacteria, mold, mildew, diseases, flu and temperatures between the floors involved. THIS IS EXACTY WHAT ACCURATE "INTERNAL BUILDING PRESSURE CONTROL", MUST PREVENT, NOT ENCOURAGE. Additionally, the duct used to "move" this air from floor to floor would in turn, act as a conduit and allow air to "uncontrollability" move between the floors involved, caring contaminants, odors, humidity, gases, biologicals, viruses, bacteria, mold, mildew, diseases, flu and temperatures, with it. Plus, it could spread a FIRE and the associate SMOKE.

Plus, just SIMPLY "pumping" air around within the same multi-floor building "vessel", may solve a "temperature" problem within a "vessel", BUT it will do NOTHING to SOLVE a SINGLE "pressure" problem within the "vessel". To SOLVE a "pressure" problem within a "vessel", air MUST be either "added" or "removed" from the "vessel", and NOT just SIMPLY "pumped" around within the SAME "VESSEL". Would simply "pumping" air around within a tire that has low pressure, increase it's pressure? NO.

As stated in previous arguments of this filing, the current FIRE CODES establishes each floor as a "SEPARATE VESSEL", within the larger, multiple floor, building "vessel". So, EACH FLOOR INVOLVED MUST BE MEASURED AND CONTROLLED INDIVIDUALLY, as I claim. The ONLY way to overcome these pressure forces, is to "measure", "analyze" and "control" them, EXACTLY as I am claiming, ONE FLOOR AT A TIME. The "delay" involved with the SINGLE interior sensor employed by ASHRAE on multiple floor buildings, dooms their scheme to FAILURE, as they "wait" for the pressure differences to equalize. If a particular air handler serves several floors of a building, then those floors would still have to "measure" individually, but might have to be "controlled", as group. If possible, EACH floor should be "controlled" individually. The "shared" air handler and its associated ductwork could allow air and pressure to "move" between the floors involved. This would not be a difficult task, for the "analyzer" and "controller" involved, to "learn" how to handle.

The "pressure control" method that I have used with GREAT effectiveness and success is, to "vary" the amount of "return air" and "outside air" SIMULTANEOUSLY, from the same chosen "pressure measurement". This method is also the FASTEST and MOST ACCURATE. The

"return air" and "outside air" are "varied" at the same time, with either a motorized "face and bypass" damper arrangement, or two separate motorized dampers, one acting in a "direct" response mode and the other acting in a "reverse" response mode, to the same command "signal" from the pressure controller. To prevent cross contamination between the various floors involved, ONLY NEWLY INTRODUCED OUTSIDE AIR should be used to "pressurize", the floors involved, and NOT "used" air from other floors, as Whitmore "theorizes". "Supply air" is usually based on the temperature design of the building and can NOT be "varied" easily, as this could leave some areas too cold, or too hot. Thereby, unacceptably sacrificing "temperature control" for "internal building pressure control". Forms of "supply air" manipulation may present themselves in the future, through the practical application of the ideas taught by this patent at hand.

The "air filtration systems" that Hartenstein claims, will NEVER survive the duration of a Chemical, Biological or Radiological attack. We stopped using them for Industrial "SAFE HAVENS" over TEN YEARS AGO, due to their propensity to FAIL just when you NEEDED them, the MOST. The "scrubber/air cleaning/air filtration" systems WILL deplete due to the volume of the attack. The resulting FAILURE ends up allowing the "air filtration system" to "pump" the contaminant DIRECTLY into the building, KILLING, EVERY ONE INSIDE. If you "stop" ALL "outside air" at the onset of an attack, then EVERYONE in the building is condemned to DEATH, as wind and "vapor pressure" drive the contaminant into the building. So, "outside air" MUST be drawn from a source at LEAST 75 FEET off of the ground (I base this height on EPA data that I used for Industrial Projects), if it is to provide protection, WHEN NEEDED. Simple 95% efficient particulate filters, regularly maintained, are ALL that are required, and they WILL last

the duration of the attack and can be easily replaced, immediately afterwards.

If we are to design buildings to withstand Chemical attacks, then a 0.10 inch water gauge of "positive" building pressure is ALL that is needed. I have 25 industrial buildings operating at this pressure, EVERY SECOND, OF EVERY MINUTE, OF EVERY DAY, in accordance with NFPA 496 requirements, TO PREVENT EXPLOSIONS, without ANY "filtration systems", as Hartenstein claims. 0.10 inch is selected because this is all that is needed to prevent the entry of deadly gases (ammonium, chlorine, etc..). The highest "vapor pressure" that ALL deadly gas generates, has a maximum "driving force" of around 850 FPM. In other words, when a deadly gas is released, it will strive to reach equilibrium within its new environment at a maximum of 850 FPM, based on BOYLE'S LAW. The applicable BERNOULLI formula for velocity pressurization is: the square root of the pressure differential, multiplied by the constant 4005, will provide the velocity that air will move from the "high" pressure "internal" area, towards the "low" pressure "outdoor" area. The square root of 0.10 inches water gauge is 0.3162277, multiplied by 4005, means that air will "leave" our "positive" pressurized buildings at 1266 FPM. This means that the 850 FPM deadly gas CAN NOT enter the building when faced with air that is "leaving" at 1266 FPM. The 416 FPM (48%) EXTRA velocity is for safety, to assure protection and allow the "building pressure control" system, time, to account for wind fluctuations.

I have NEVER operated a building at more than a 0.20 inch water gauge "positive" pressure and I do not see any reason why a higher "positive" pressure than 0.10 inch water gauge, would EVER be required. I have read very little about "nerve gas", but what I have read leads me to

believe that it's "driving force" is only around 500 FPM, due to the chemicals involved. Biological attack elements have NO motility, so wind velocity is the only challenge to overcome and prevent their entry into a building. The same is true for a Radiological attack, other than for the explosive effect of the bomb itself.

I can provide references where I did keep an Industrial Project at a 0.20 inch "positive" pressure and we almost killed a maintenance worker when he opened the entry door. It flew open so fast, that he was almost thrown off of a second story entry balcony. At a 0.20 inch "positive" pressure, air is "moving" outwards at 1791 FPM (20 MPH). The Whitmore patent mentioned ONLY being able to measure 1.0 inch to 10.0 inch pressures, this would be TOTALLY impractical as it would "move" air outwards at velocities from 4005 FPM (45 MPH) (1.0") to 12,665 FPM (144 MPH) (10.0"). This would eventually dislodge exterior windows, blow open exterior doors, throw people down stairways, prevent proper air handler operation, create new leaks in the "skin" of the building, do the same between floors and cause MANY other problems that PREVENT accurate "building pressure control". Whitmore does NOT understand "building pressure", making his "theory" simply IMPRACTICAL.

<u>APPLICANT REPLIES TO INTERNET SEARCH BY EXAMINER AND SUIPERVISOR</u>

The Barcol-Air data supplied by the examiner, has been reviewed and is simply a standard "duct static-pressure control system" as described fully in Chapter 46, page 2, and shown in Fig. 5 on the same page of the 2003 ASHRAE Applications Handbook, please see attached exhibit U. This ASHRAE drawing is EXACTLY like the Barcol-Air drawing

supplied. This is in NO way what the Applicant is claiming, in the patent at hand.

The name Barcol-Air is derived from the old Barber Coleman Company. I have done many "pressure control" systems with Barber Coleman over the years, including several Hospitals. In fact I buy averaging and high-low ("maximum-minimum") select "relays" from the local Barber Coleman/Barcol-Air Representative, to use on my patented "building pressure systems". Barber Coleman NEVER was, and Barcol-Air is currently NOT, actively involved in **DIRECTLY** measuring "internal building pressure". Their background for the past fifty years is in "air control".

They manufacturer and sell very accurate "flow measurement and control systems", NOT **DIRECT** "internal building pressure" measurement and/or control systems, as I claim. Barcol-Air is simply using their extensive background in "flow measurement and control" in a COMMON and STANDARD "flow tracking" scheme that SIMPLY involves balancing supply air flows to match (neutral space pressure), or exceed (positive space pressure), or be less than (negative space pressure) the exhaust air flows plus return air flows, to control space pressures. They do NOT include ANY "internal space" pressure sensors, as Applicant claims.

Barcol-Air is simply adding pressure sensors in the supply air ducts, to assure that the supply volumes are stable and can be accurately measured. These systems ALWAYS fail to accurately determine "internal" building pressure because they NEVER know the "infiltrated" or "exfiltrated" air "flows", that enter through the building's "skin". Applicant's current invention ACCURATELY accounts for these infiltrated and exfiltrated "skin" air "flows". No other known "building pressure

measurement or control" system currently does, other than this patent at hand and the Applicant's granted patent numbers 6,584,855 and 6,968,745. This is a simple FACT, which separates me from ALL before me.

NO WHERE is this Barcol-Air data does the Applicant find A SINGLE reference to "providing at least one pressure sensor on at least two of said multiple floors"; NOR dose Barcol-Air EVER say "a connection means to the pressure sensors"; and NEVER "attaching an analyzer to said pressure sensors for receiving input from said pressure sensors and comparing at least one pressure reading from one floor with another pressure reading from at least one of the other multiple floors of said building", as I claim. Please show me a single sentence that refutes my assertion.

Applicant has reviewed the article supplied by the Examiner and his Supervisor, that is authored by Joseph Lstiburek, titled "Air Pressure and Building Envelopes" and again finds NOT A SINGLE reference to "providing at least one pressure sensor on at least two of said multiple floors"; NOR dose Mr. Lstiburek EVER say "a connection means to the pressure sensors"; and NEVER "attaching an analyzer to said pressure sensors for receiving input from said pressure sensors and comparing at least one pressure reading from one floor with another pressure reading from at least one of the other multiple floors of said building", as I claim. Please show me a single sentence that refutes my assertion.

MOST of the time, Joseph ONLY uses hand held pressure measurement devices, such as a "micromanometer" (see exhibit E) and "portable digital manometers" (see exhibit F). This means that he has NO way of "connecting to the pressure sensors"; so he could NEVER "attach an analyzer to said pressure sensors for receiving input from said pressure

sensors and comparing at least one pressure reading from one floor with another pressure reading from at least one of the other multiple floors of said building", as I claim.

Even when he is diagnosing problems in a multiple floor building, Mr. Lstiburek NEVER, DIRECTLY, compares "a pressure measurement from one floor with another pressure reading from at least one of the other multiple floors" as I claim. He does take pressure measurements in some of the SAME interstitial spaces that I want to measure in, BUT he does so on ONLY, ONE FLOOR AT A TIME, AND THEN HE DOES **NOT** COMPARE THAT PRESSURE MEASUREMENT, TO **ANY** OTHER PRESSURE MEASUREMENT FROM **ANOTHER** FLOOR OF THE BUILDING, as I claim. Please see exhibits G, H and I, along with figures 10, 11 and 12. Since the pages of this article are not numbered, I will attach copies of referenced excerpts as marked exhibits. For brevity, I will not attach copies of his figures.

Please see attached exhibit E and F along with his figure 6, which shows Mr. Lstiburek measuring the pressure on ONLY ONE FLOOR at a time. And what does he compare this pressure measurement in ALL cases to, OUTDOORS/EXTERIOR, and NOT DIRECTLY to ANY OTHER floor of the building, as I claim. Even when he is "pressurizing the floors above and below the test floors as well at the elevator shafts to identical pressures to the test floor", how does he determine the pressure of an individual floor? BY "COMPARING" THE INDIVIDUAL FLOOR TO "THE EXTERIOR", AND NOT TO A PRESSURE READING FROM ANOTHER FLOOR. ONLY THEN does he "compare" this "INDOOR-TO-OUTDOOR" relationship to a SIMILAR "INDOOR-TO-OUTDOOR" relationship from another floor. This is NOT what I am claiming. I NEVER claim ANY desire to "comparing at least one pressure reading from one floor to the EXTERIOR/OUTDOORS and then

compare this "INDOOR-TO-OUTDOOR" relationship to a similar "INTERIOR-TO-OUDOOR" pressure relationship from at least one of the other multiple floors of said building", as Lstiburek discloses.

This scheme will NEVER work accurately during periods of high winds, or turbulence. I tried this EXACT scheme back in 1998, and this comparison NEVER, ACCURATELY measured how much air is "infiltrating" and "exfiltrating" on "a particular floor", or the "building as a whole". Regardless of the type of "corrective" mathematical modeling, I attempted. In other works, turbulence on the exterior sensor, prevents its reading from being ACCURATELY linked, to what is actually occurring on a particular floor, even when mathematical corrections are employed. As confirmed by Mr. Lstiburek on exhibit I when he says, "Using the exterior air pressure as a reference pressure is **impractical** due to the high variability of the boundary layer air pressure regime". This is EXACTLY why Mr. Lstiburek says "Air pressure measurements were taken during **calm** weather in April" This patent at hand and my granted patents do NOT suffer from these limitations I even tried "barometric" pressure sensors in over thirteen FAILED schemes. They were just too SLOW.

Please do not operate under the illusion that I happened on my granted patents, or this patent at hand, EASILY. I literally made HUNDREDS of FAILED attempts at "building pressure measurement and control", BEFORE I found the method of "measuring the **dynamic** pressure of air as it flows THROUGH the exterior walls ("skin") of a multiple floor building", that was granted. Similarly, I have endured HUNDREDS of FAILED attempts at an "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD", BEFORE; I filed this patent at hand. I tried so MANY variations of BOTH that TSI wrote and told me that they did NOT think that accurate "building pressure

measurement and control" was possible, and they were tired of wasting valuable resources, "trying". They wrote me and advised that all future attempts would incur an ADDITIONAL $4,000.00 "programming cost". But I kept on "trying" and FINALLY found schemes that WORKED, that were NEW, NOVEL and NON-OBVIOUS, and then filed patents on what I "learned".

I hereby declare, that in 1996, I determined that someday, ACCURATE, "BUILDING PRESSURE MEASUREMENT AND CONTROL" would become EXTREMELY IMPORTANT. I made a COMMITMENT to myself that I would NEVER, STOP, "trying" until I SUCCEEDED. I say it was this COMMITMENT that kept me going during the darkest days, like these. My 18 years of experience lead me to believe that if anyone could "crack the code on building pressure", as I called it, it could be me. I literally spend hundreds of thousands of dollars in my quest. AND I SAY I HAVE FINALLY SUCCEEDED. I turn to Sir Edmund Hillary for the reason I SUCCEEDED, "ONE CAN NOT IMMAGINE WHAT ALL MANNER OF THINGS IN THE UNIVERSE WILL COME TO ONES AID, ONCE ONE IS COMMITTED".

Additionally, Mr. Lstiburek is making these "INDOOR-TO-OUTDOOR" pressure measurements on individual floors with "blower doors" and portable digital manometers, and he NEVER mentions "connecting to the pressure sensors" from the floors involved; so he could NEVER "attach an analyzer to said pressure sensors for receiving input from said pressure sensors and comparing at least one pressure reading from one floor with another pressure reading from at least one of the other multiple floors of said building", as I claim Mr. Lstiburek is simply MANUALLY "analyzing" the "blower door" generated pressure on an individual floor, TO OUTDOORS/EXTERIOR. Then MANNUALLY "controlling/regulating" the

pressure on said individual floor, TO OUTDOORS/EXTERIOR, by MANUALLY "comparing" the "INDOOR-TO-OUTDOOR" relationship of said individual floor to the "INDOOR-TO-OUTDOOR" relationship, of the other two floors involved. I NEVER claim MANUAL operation in my scheme. It would be too slow to EVER produce acceptable results. MANUAL operation serves Mr. Lstiburek, because speed is NOT important and at the end of the day he ONLY using "pressure measurements" to determine VOLUMES.

During another part of the same test, he even goes so far as to maintain the floors above and below the floor being tested/measured, at exterior pressure by opening all windows and corridor doors, on those floors, please see attached exhibit E. By this procedure Mr. Lstiburek is CLEARLY just trying to determine the pressure on ONLY ONE FLOOR AT A TIME. THE FLOOR IN THE MIDDLE.

After completing BOTH of the above test methods on EACH floor INDIVIDUALLY, to OUTDOORS, with this "blower door" arrangement, he then takes the VOLUMES the "blower door" measured to pressurize that particular floor, to OUTDOORS, "TO **APPROXIMATELY** 25 PASCALS", please see exhibit G and figures 7 and 9. Then Joseph uses a smoke pressurization and smoke extraction system, BASED ON THESE VOLUMES, to isolate the floor with a fire on it. In other words, at the end of the day, Mr. Lstiburek is using the VOLUMES he measured with the "blower doors", to keep the floors at different pressures and **NOT, ANY FORM OF A DIRECT** pressure measurement scheme, as I claim. He did go further than ASHRAE, by employing more than a SINGLE indoor "pressure" sensor, but then ONLY "comparing" their readings to OUTDOORS, doomed his ideas to FAILURE. Mr. Lstiburek KNEW this and that is why he ended up using VOLUMES to control pressure, INSTEAD of ANY FORM OF DIRECT pressure measurement,

as I claim. This is further proof that my ideas are NEW, NOVEL and NON-OBVIOUS.

More proof of the fact that he compares ALL of his pressure measurements to OUTDOORS, are Mr. Lstiburek's figures 5, 6, 7, 9, 10,11 and 12. ALL of these drawings show the same pressure for all of the connected floors. Think about it, this would be IMPOSSIBLE if he was comparing the pressures of the various floors to each other if one floor is at a "positive" pressure in a "floor to floor comparison" scheme, then one of the floors next to it, MUST be at a "negative" pressure, by "comparison". This is another reason the pressure transducer Whitmore is patenting would NOT work for "internal building pressure", it is INCAPABLE of producing a "negative" pressure reading. It would produce a pressure reading but then how would you know if that reading were a "positive" pressure relationship, or a "negative" pressure relationship, to the "compared" floor. The ONLY time multiple floors are EVER at the SAME pressure is when they are residing at a "neutral" pressure, in "comparison" to each other. The ONLY way ALL of the floors involved could be at a "positive" pressure, or ALL at a "negative" pressure, as Mr. Lstiburek's figures show, is when they are being "compared" to a COMMON pressure, OUTDOORS.

Attached exhibits H and I and figures 10, 11 and 12 shows Mr. Lstiburek on another project with permanently mounted "pressure sensors". Once AGAIN comparing the "pressure" data that he does receive, TO OUTDOORS, and NOT TO THE PRESSURE OF ANY OTHER FLOOR OF THE BUILDING. Again, Mr. Lstiburek NEVER says "providing at least one pressure sensor on at least two of said multiple floors"; NOR dose Mr. Lstiburek EVER say "connecting to the pressure sensors"; and NEVER "attaching an analyzer to said pressure sensors for receiving input from

said pressure sensors and comparing at least one pressure reading from one floor with another pressure reading from at least one of the other multiple floors of said building", as I claim. Please show me a single sentence that refutes my assertion.

In ALL of the multiple floor projects in this article, Mr. Lstiburek compares ALL of his individual floor pressure readings, ONLY TO OUTDOORS. Mr. Lstiburek is very active in ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers). In fact, Mr. Lstiburek is an ASHRAE Fellow, recognized for his significant contributions to ASHRAE. This means he is far more likely to follow ASHRAE guidelines, THAN TO QUESTION THEM. He wants to fit in and be a good ASHRAE "company" man.

ASHRAE says that the 'internal' building pressure sensor should ONLY be, COMPARED TO OUTDOORS. A fact I will address in length, later in this reply. Joseph is simply following ASHRAE guidelines and is NOT thinking out side of the ASHRAE 'box'. ASHRAE, NEVER, ONCE, mentions, discloses, or suggest, "comparing at least one pressure reading from one floor with another pressure reading from at least one of the other multiple floors of said building", as I claim. So, Joseph NEVER does, EITHER. If, Whitmore HAD established the "state of the art" for an "internal building pressure measurement and control, method and apparatus", then ASHRAE and Mr. Lstiburek would have employed it. BUT THEY DID NOT.

Mr. Lstiburek owns a company called Building Science Corporation that is called in to diagnose and solve "problem buildings", as the article provided by the Examiner and his Supervisor, verifies. I hereby declare that I traded emails with Mr. Lstiburek back in December of 2005, after a

mutual friend, Mr. Mark Nunnelly, P.E. (205-425-0060 or 205-516-4064)(we both graduated from Auburn University) introduced us through an email I hereby declare that I have NEVER communicated with Mr. Lstiburek concerning "internal building pressure", or "building pressures", of ANY kind. I also hereby declare that was the first time I had ever seen his name, or ever heard of him, or ever read ANY of his articles. I have had NO contact with him since them.

Mark Nunnelly emailed me an article Joseph wrote about rebuilding homes after hurricane KATRINA. In that article, the article that the Examiner noted, plus over ten other Lstiburek articles that I have now read, does Mr. Lstiburek EVER mentions, discloses, or suggest, "comparing at least one pressure reading from one floor with another pressure reading from at least one of the other multiple floors of said building", as I claim. I had hoped to establish a friendship with Mr. Lstiburek, but now I am forced to attack his findings.

The real TRUTH can be CLEARLY SEEN in ALL of Mr. Lstiburek's **"Conclusions"** and **"Rehabilitation Measures"** that are shown in exhibits E through H. He NEVER ONCE discloses implementing floor to floor, "internal building pressure" measurement and/or control to solve the problems he is diagnosing, as I claim. Mr. Lstiburek NEVER ONCE mentions "providing at least one pressure sensor on at least two of said multiple floors"; NOR dose Mr. Lstiburek EVER say "connecting to the pressure sensors"; and NEVER "attaching an analyzer to said pressure sensors for receiving input from said pressure sensors and comparing at least one pressure reading from one floor with another pressure reading from at least one of the other multiple floors of said building", as I claim. Please show me a single sentence that refutes my assertion.

In ALL of these "**Conclusions**" and "**Rehabilitation Measures**" Joseph is ONLY treating the SYMPTOMS of the problems that he is diagnosing. Which means he does NOT, COMPLETELY UNDERSTAND THE TRUE PROBLEM, so he has NO idea of how the CURE the problems he is diagnosing. His PRIMARY method of treading "building pressure" problems, is by "SEALING" the building up, better, and better, please see exhibits K, L and O. These measures are just treating the SYMPTOMS of the problem, and ALWAYS fail to CURE the problem, in the LONG RUN. ALL of my patents, including the one at hand, are the COMPLETE CURE for the problems, Mr. Lstiburek is diagnosing. I think that I could help Joe SOLVE some of the building pressure problems, which he is diagnosing, by using fast and accurate "building pressure control" systems as described in this patent and my granted patents. Especially in light of Mr. Lstiburek's own words "Using exterior air pressure as a reference pressure is impractical due to the high variability of the boundary layer air pressure regime", see attached exhibit I. NONE of my patents suffer from this limitation Plus, Mr. Lstiburek NEVER mentions comparing the pressure of the various floors as a reference pressure. Please correct me if I am wrong.

In fact, Mr. Lstiburek makes the point for the Applicant's patent at hand. In his **Abstract** on page one of this article, exhibit A. Mr. Lstiburek clearly states the "need" for "control of air pressures", but he NEVER says that this can be accomplished by "comparing a pressure reading from one floor with the pressure reading from another floor", as I claim. In fact, Mr. Lstiburek NEVER says exactly how to control building pressure He primarily says that the problem is a result of the "interaction of the building envelope with the mechanical system". These words are taken almost verbatim from page 27.6. of the 2005 ASHRAE Handbook on

Fundamentals, please see the marked lines on exhibit X, which once again confirms Mr. Lstiburek's connection to ASHRAE. These words speak volumes about EXACTLY how Mr. Lstiburek thinks building pressure problems occur, "either through the building envelope" or the building's "mechanical system". He completely ignores the "floor to floor pressure relationship" as part of the problem. Through this **Abstract**, and this entire thesis, Mr. Lstiburek completely refutes the Examiner's assertions made in his **Response to Arguments** that were mailed to the Applicant on 03/09/2006, that "the thermostat may be construed as controlling the pressure"

I want to reiterate, the fact, that by putting air into the various floors of a multiple floor building, based solely on a temperature and/or humidity basis, will actually generate the very "errant pressure bubbles", that the Applicant has discovered within buildings through the application of his granted patents and is now attempting to correct, with the patent at hand.

APPLICANT SEARCHES THE INTERNET FOR PRIOR ART FOR "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD"

Applicant feels he MUST search the internet for prior art concerning an "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD", in order to move this patent through the process. Using the method established by the Examiner and his Supervisor, Applicant "googled" the following topics and now lists ALL of the articles that could possibly apply, to the patent at hand.

1) I "googled" "building floor pressure" and found the following;

www.bits-testlab.co.uk/ -105k
www.buildingscience.com/buildingamerica/target.htm-18k
building airflow.lbl.gov/APT - TMS.html-14k
Link.aip.org/link/?jaeled/8/108/1

2) I "googled" "building floor pressures" and found the following;

www.bits-testlab.co.uk/ -105k
www.buildingscience.com/buildingamerica/target.htm-18k
building airflow.lbl.gov/APT - TMS.html-14k
www.eeba.org/tecgbiklgv/criteria.htm-13k
Link.aip.org/link/?jaeled/8/108/1

3) I "googled" "building pressure per floor" and found the following;

www.buildingscience.com/building America/target.htm-18k
buildingairflow.lbl.gov/APT - TMS.html-14k
www.attmaorg/ATTMA_TS1_Issue_1_March_06.pdf
192.19769.104/publications/en/rh-pr/tech/98123.htm-16k
freepatentsonline.com/4606228.html-25k

4) I "googled" "building pressures per floor" and found the following;

www.buildingscience.com/building America/target.htm-18k
buildingairflow.lbl.gov/APT - TMS.html-14k
www.attmaorg/ATTMA_TS1_Issue_1_March_06.pdf
192.19769.104/publications/en/rh-pr/tech/98123.htm-16k
freepatentsonlinecom/4606228.html-25k

5) I "googled" "controlling floor pressure" and found the following;

www.hpl.hp.com/techreports/2006/hpl-2006-47.pdf

www.cbeberkeley.edu/underfloorair/exampleLayout-htm-17k
www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/98123.htm-50k

6) I "googled" "controlling floor pressures" and found the following;
www.hpl.hp.com/techreports/2006/hpl-2006-47.pdf
www.cbeberkeley.edu/underfloorair/exampleLayout-htm-17k

7) I "googled" "floor pressure" and found the following;
buildingairflowlbl.gov/pubs/WhatToMeasure.pdf
www.buildingseincecom/resources/walls/air_pressure_envelopes
www.hpl.hp.com/techreports/2006/hpl-2006-47.pdf
meetingsaps.org/meeting/DFD05/Event/36705-4k
www.pecl/org/ftguide/ftg/Test_Guidance/ Test/TG12-envelope_Leakage.doc

8) I "googled" "floor pressures" and found the following;
www.buildingseincecom/resources/walls/air_pressure_envelopes
buildingairflowlbl.gov/pubs/WhatToMeasure.pdf
www.hpl.hp.com/techreports/2006/hpl-2006-47.pdf
meetingsaps.org/meeting/DFD05/Event/36705-4k
www.peci/org/ftguide/ftg/Test_Guidance/ Test/TG12-envelope_Leakage.doc

9) I "googled" "individual floor pressure" and found the following;
www.cbe.berkeley.edu/underfloorair/tacguidelineshtm-28k
www.oasisopen.org/committees/dwonload.php/9598/UseCases.01

10) I "googled" "individual floor pressures" and found the following;
www.cbe.berkeley.edu/underfloorair/tacguidelineshtm-28k

www.oasisopen.org/committees/dwonload.php/9598/UseCases.01.
Doc
192.19769.104/publications/en/rh-pr/tech/98123.htm-16k

11) I "googled" "measuring floor pressure" and found the following;
buildingairflowlbl.gov/pubs/WhatToMeasure.pdf
www.ebtron.com/Applications/ebtron_Applications_design_
overviewhtm-71k

12) I "googled" "measuring floor pressures" and found the following;
buildingairflowlbl.gov/pubs/WhatToMeasure.pdf
www.ebtron.com/Applications/ebtron_Applications_design_

13) I "googled" "measuring pressure between floors" and found the following;
buildingairflowlbl.gov/pubs/WhatToMeasure.pdf
www.buildingseincecom/resources/walls/air_pressure_envelopes
www.fsecucf.edu/bldg/pubs/commission-airflow/index.htm-50k
www.attmaorg/ATTMA_TS1_Issue_1_March_06.pdf
192.19769.104/publications/en/rh-pr/tech/98123.htm-16k
freepatentsonlinecom/4606228.html-25k
www.homeenergy.org/archive/
hem.dis.anl.gov/eehem/95/951111.html-36
www.kchero.com/rating.html-28k

14) I "googled" "measuring pressures between floors" and found the following;
buildingairflowlbl.gov/pubs/WhatToMeasure.pdf
www.fsecucf.edu/bldg/pubs/commission-airflow/index.htm-50k

www.buildingseincecom/resources/walls/air_pressure_envelopes
www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/98123.htm-50k
www.attmaorg/ATTMA_TS1_Issue_1_March_06.pdf
192.19769.104/publications/en/rh-pr/tech/98123.htm-16k
freepatentsonlinecom/4606228.html-25k
www.buildingscience.com/resources/
misc/pressure_response_building.pdf
www.natresnet.org/standards/ interpretation-duct_test.pdf
www.homeenergy.org/archive/
hem.dis.anl.gov/eehem/94/940908.html-34

15) I "googled" "measuring pressure per floors" and found the following;
buildingairflowlbl.gov/pubs/WhatToMeasure.pdf
www.fsecucf.edu/bldg/pubs/commission-airflow/index.htm-50k
www.buildingseincecom/resources/walls/air_pressure_envelopes
www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/98123.htm-50k
www.attmaorg/ATTMA_TS1_Issue_1_March_06.pdf
www.pecl/org/ftguide/ftg/Test_Guidance/ Test/TG12-
envelope_Leakage.doc
192.19769.104/publications/en/rh-pr/tech/98123.htm-16k

16) I "googled" "measuring pressures per floors" and found the following;
buildingairflowlbl.gov/pubs/WhatToMeasure.pdf
www.fsecucf.edu/bldg/pubs/commission-airflow/index.htm-50k
www.buildingseincecom/resources/walls/air_pressure_envelopes
www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/98123.htm-50k

www.attmaorg/ATTMA_TS1_Issue_1_March_06.pdf
www.pecl/org/ftguide/ftg/Test_Guidance/ Test/TG12-
envelope_Leakage.doc
192.19769.104/publications/en/rh-pr/tech/98123.htm-16k

17) I "googled" "pressure between floors" and found the following;
www.buildingsciencecom/building America/target.htm-18k
building airflow.lbl.gov/APT - TMS.html-14k
www.epa.gov/iaq/schools/tfs/guide 2 html-54k
www.infogov.hk/info/ap/pde/amoy_e.pdf

18) I "googled" "pressures between floors" and found the following;
www.buildingsciencecom/building America/target.htm-18k
building airflow.lbl.gov/APT - TMS.html-14k
www.epa.gov/iaq/schools/tfs/guide 2 html-54k
www.infogov.hk/info/ap/pde/amoy_e.pdf

Applicant found one article out of the thirty listed above, that needs to be addressed. It is the above listed"freepatentsonline.com /4606228", on United States patent number 4,606,228. I hereby declare that the FIRST time I EVER saw this patent was during this search on Saturday, April 29, 2006. Mr. Whitmore NEVER "claims" what Applicant "claims". Previous arguments on this filing include references as to why Whitmore failed to establish the "state of the art" for an" INTERNAL BUILDING PRESSURE APPARATUS AND METHOD", as I am claiming. The following is a list of reasons why Applicant's patent at hand is NOT anticipated by Whitmore per the requirements of 35 U.S.C. § 102. NOR did patent number 4,606,228 establish the "state of the art" for the "subject matter" taught by the Applicant, so the patent at hand should NOT be

rejected under 35 U.S.C. § 103, second paragraph, for the previous arguments and the following:

1. Whitmore's stated "object of the present invention to provide a small, light and therefore gravity insensitive and inexpensive diaphragm structure for pressure transducers, particularly of the capacitance type, for the measurement of low pressure differentials." This is the "subject matter" of the Whitmore patent and his goal is to establish a "state of the art" pressure transducer that contains his "diaphragm" NOTHING here establishes the "state of the art" for an "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD", as I am teaching.

2. To use Whitmore's own words, his "diaphragm" COULD be used in an "energy management control system" to take pressure "measurements for the purpose of knowing where the air is moving, or trying to move. There may, for example, be openings which will allow air to move between floors of a multi-floor building so as to cause much of the warm air to move to the upper floors. With proper measurement to detect movement a computer may be used to calculate the action necessary from an associated control system to pump air back to the lower floors." Thorough these words he is "theoretically" expanding the uses of his "diaphragm" as an "energy management and temperature control system". AND THAT IS ALL HE IS DOING!! His stated "theory" does NOT even involve an "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD", IN ANY WAY, SHAPE OR FORM.

3. His primary "theory" here is to save energy and provide better temperature control, Whitmore NEVER says a SINGLE word about "pressure control", of any kind.

4. He is operating under the illusion that "warm air rising" is a problem in multiply floor buildings. So, IF he had ever tried to employ his "theory" for these uses, he would have FAILED. He does NOT see the COMPLETE PROBLEM, so he has NO CURE for it.

5. The REAL TRUTH about "energy savings" and "temperature control" in multiple floor buildings, is that it takes approximately FOUR TIMES as much energy to treat "infiltrated" air that is "sucked/pulled" into a building through it's "skin", as it does to "precondition" the outdoor air used to "pressurize" the same building, and PREVENT uncontrolled "infiltration". I have read over ten articles on this very issue. I have also read several other articles that prove that "uncontrolled 'infiltration" can easily exceed the capability of an HVAC system to manage indoor temperature and humidity and keep the indoor environment within design limits". MANY of the 634,000 articles prove this. ALL of my granted patents and this patent at hand WILL SOLVE ALL OF THESE "REAL" PROBLEMS. Whitmore's "theory", would NEVER SOLVE ANY OF THEM, or ANY OTHER "REAL" PROBLEM.

6. Whitmore FAILED to see the TRUE problem, so his scheme NEVER established the "state of the art" for the patent at hand.

7. IF he had established the "state of the art" for "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD", then ASHRAE, Mr. Lstiburek and MOST of the people involved in the aforementioned 634,000 articles, WOULD have employed it. It has been 21 years since he wrote down his "theory" and I could NOT find ANYONE that employed ANY form of "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD" based on his "temperature theory". If ANYONE had employed them, I would have

heard about it, or seen it "Building pressure" has been my life's work for over 28 years.

8. Just "suggesting" a "theoretical" use of his "diaphragm" invention, FAILS to meet the requirements of 35 U.S.C. § 102, or 35 U.SC. § 103, to reject the patent at hand. NONE of his "claims" disclose the patent at hand and his "subject matter" is TOTALLY different The "learned" individuals of ASHRAE have "extraordinary" skill in the field of an "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD", not just "ordinary skill" as required to reject under 35 U.S.C. § 103, second paragraph, and they NEVER accepted Whitmore's "theory" as establishing ANY "prior art" concerning "INTERNAL BUILDING PRESSURE", and NEITHER do I.

9. Whitmore refers to "low pressure differentials (such as 1.0" to 10.0" of water full scale)". As pointed out in previous arguments within this filing, these are EXTREMELY HIGH pressure differentials for the floors of buildings. These words speak volumes to his lack of understanding of the TRUE problem, and the CORRECT solution. His "diaphragm" would NEVER have produced a SINGLE usable "building pressure" measurement. As mentioned previously, the MAXIMUM pressure a floor of a building, or the building as a whole should be limited to 0.10" WG, TO OUDOORS. The "lowest" pressure measurement POSSIBLE with Whitmore's "diaphragm" is 1.0" WG. This is TEN TIMES what's required and FIVE TIMES more than I have EVER seen used in "BULDING PRESSURE". By the time his scheme reacted, windows would be damaged, NEW "leaks" would have been "blown" in exterior walls and outward opening doors would NEVER close, thereby "blowing" building pressure. Whitmore's "diaphragm" CAN NEVER BE USED FOR "INTERNAL BUILDING PRESSURE MEASUREMENT OR CONTROL".

10. The primary GOAL of the patent at hand is to maintain the various floors involved a UNIFORM pressure in relationship to each other, as I clearly state on page 2, lines 5-13, of my application. The Whitmore "diaphragm" is NOT even capable of measuring ANYTHING near this. This means that I want to maintain ALL of the various floors at a "neutral" pressure relationship. The truth is that 0.000" WG has proven difficult to maintain, so I will attempt to maintain the various floors at a 0.00005" WG relationship. This relates to 28 FPM of air movement between the floors, which is limited ONLY by current "pressure" sensor technology, which may improve in the future, and I will employ it then. Whitmore's "diaphragm" would NEVER produce a SINGLE useful "pressure" measurement, at these levels. This 0.00005"WG requirement is 20,000 (twenty thousand) times LOWER than Whitmore's LOWEST POSSIBLE READING. By the time Whitmore produced his FIRST usable pressure measurement of 1.0"WG, you could LITERALLY fly a kite in the 45MPH winds that would exist between the various floors.

11. Additionally, as the previous paragraph discloses, I want to maintain a "neutral" floor-to-floor "pressure" relationship. This means that various floors will CONSTANTLY fall BELOW this goal, which means a "NEGATIVE" pressure MUST be measured. ALL of the pressure differentials that the Whitmore "diaphragm" can measure are POSITIVE. What would happen when he encountered a NEGATIVE floor-to-floor "comparison"? He would NEVER know it. He would automatically assume it was a POSTITIVE relationship and make an already BAD problem worse. I have "seen" this occur when using sensors that could NOT detect a POSITIVE "pressure" reading from a NEGATIVE "pressure" reading. My scheme MUST know WHETHER the relationship of the floors is NEGATIVE or POSITIVE, BEFORE the "controller" decides what corrective actions to take. Whitmore's "ideas"

would FAIL to "accurately" provide "INTERNAL BUILDING PRESSURE MEASUREMENT OR CONTOL".

12. In lieu of the above THREE numbered paragraphs, I hereby declare that the pressure transducer that includes the Whitmore "diaphragm" as described in his patent, could NEVER be used in an "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD", that I am teaching. I hereby declare I will NEVER use one of his "diaphragms"; it will cause more DAMAGE and PROBLEMS, that SOLUTIONS

13. As stated previously, Whitmore's "theory" involving "pumping" air back down to the lower floors, from the upper floors, would just spread contaminants, odors, humidity, gases, biologicals, viruses, bacteria, mold, mildew, diseases, flu and temperatures between the floors involved. THIS IS EXACTY WHAT ACCURATE "INTERNAL BUILDING PRESSURE CONTROL", MUST PREVENT, NOT ENCOURAGE.

14. Plus, just SIMPLY "pumping" air around within the same multi-floor building "vessel", might solve a "temperature" problem within the "vessel", BUT it will NEVER do ANYTHING to SOLVE a SINGLE "pressure" problem within the same "vessel". To SOLVE a "pressure" problem within a "vessel", air MUST be either "added" or "removed" from the "vessel", and NOT just SIMPLY "pumped" around within the SAME "VESSEL", as Whitmore "theorizes". Would simply "pumping" air around WITHIN a tire with "low air pressure", solve the problem. NO.

15. As stated in previous arguments in this filing, the upper floors of buildings are already suffering from DRAMATIC losses of air through "exfiltration", Whitworth's "theory" of "pumping" air from these upper

floors would just exacerbate an already BAD, NEGATIVE pressure situation on these upper floors and cause MORE problems than it would solve.

16. To COMPLETELY SOLVE a problem, one MUST FIRST COMPLETELY understand the problem. Up until that MOMENT one is ONLY "treating" the SYMPTOMS of the TRUE PROBLEM. Which is EXACTLY what ASHRAE, Mr. Lstiburek, Mr. Whitmore, Mr. Hartenstein and ALL BEFORE ME are doing. I offer the COMPLETE CURE for ALL of the problems they are encountering.

17. ALL of the arguments against Whitmore, in this filing, accumulate into the obvious FACT that "WHITMORE KNOWS NOTHING ABOUT INTERNAL BUILDING PRESSURE", in multiple floor buildings. Even his own words NEVER disclose a floor-to-floor "pressure control" scheme. He might understand something about "temperature control", and this is ALL his "theory" involves. His "temperature control" "theory" could NEVER be used to develop an ACCURATE "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD", as Applicant claims. In light of 35 U.S.C. § 102, and 35 U.S.C. § 103, Whitmore FAILS to establish ANY "prior art" on the issue.

Applicant has reviewed ALL of the above articles and other that the "temperature remediation" "theory" proposed by Whitmore, finds NOT A SINGLE reference to "providing at least one pressure sensor on at least two of said multiple floors"; NOR did Applicant EVER find ANY words similar to

"connecting to the pressure sensors"; and NEVER "attaching an analyzer to said pressure sensors for receiving input from said pressure sensors and comparing at least one pressure reading from one floor with another pressure reading from at least one of the other multiple floors of said building", as I claim Please show me a single sentence in one of these

articles that refutes my assertion

Applicant respectfully request that Examiner again "google" "building pressure and indoor air quality" and read several more of those 634,000 articles. Almost ALL of them point to the need for a fast and accurate "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD", which is what the Applicant has invented and is now teaching, through this NEW, NOVEL and NON-OBVIOUS, patent at hand. If Whitmore has established the "state of the art" for an "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD", then at least ONE of these problem buildings WOULD have employed it. BUT NO ONE DID. The ONLY way to overcome these pressure forces, is to "measure", "analyze" and "control" them, EXACTLY as I am claiming, ONE FLOOR AT A TIME. The "delay" involved with the SINGLE interior sensor employed by ASHRAE on multiple floor buildings, dooms their scheme to FAILURE.

APPLICANT EXTABLISHES THE PRIOR ART FOR "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD"

Applicant feels he MUST establish the prior art concerning an "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD", in order to move this patent through the process. The attached eleven pages of exhibits marked P-Z, are all that ASHRAE says about "internal building pressure control". In ALL cases ONLY a SINGLE "internal" pressure sensor is mentioned, as discussed in the marked paragraphs along with figure 4 on exhibit T, plus figure 8 on exhibit U. ASHRAE is the World leader in "pressure control", and they repeated say that ONLY a SINGLE "internal" pressure sensor is required to determine "internal" building pressure. They are

WRONG.

I ask the simple question "which floor do you mount this SINGLE 'interior' pressure sensor on"? The 18th floor, maybe the 1st or could it be the 6th? There is NO correct answer. The "internal" pressure on the 18th floor can NEVER be accurately related to the "internal" pressure on the 1st floor, or the "internal" pressure of ANY OTHER floor, UNLESS said other floor has ANOTHER "internal" pressure sensor installed on it, as I claim if Whitmore HAD established the "state of the art" for "internal building pressure measurement and control", then ASHRAE and Mr. Lstiburek would have employed it.

This is why Mr. Lstiburek opened the floors above and below the floor he was measuring, to OUTDOORS, and ALWAYS "compared" interior pressures to outdoors ASHRAE'S teachings, limited Mr. Lstiburek's view of the situation He did go further than ASHRAE, by employing more than a SINGLE indoor "pressure" sensor, but then ONLY "comparing" their readings to OUTDOORS, doomed his ideas to FAILURE, for the reasons mentioned previously. That is why, at the end of the day, he HAD to use VOLUMES to "control" the "pressures" of the various floors, and NOT, DIRECT PRESSURE MEASUREMENTS, as I claim. ASHRAE NEVER compares the 'internal' pressure of one floor to the 'internal' pressure of another floor, as I claim. So Mr. Lstiburek NEVER compares the 'internal' pressure of one floor to the 'internal' pressure of another floor. He NEVER thought ANYTHING ELSE was needed, or possible, or he would have done it. ASHRAE's teachings will ONLY, ACCURATELY, "measure" and/or "control" the pressure of single floor buildings, which is why I am teaching a method and apparatus that involves "buildings with MULTIPLE floors", that is NEW, NOVEL and NON OBVIOUS.

The REAL TRUTH about how ASHRAE views pressurizing ALL of the floors "UNIFORMLY", as I state is necessary on page 5, lines 5-13, of my original patent application, are CLEARLY stated on page 27.8 of the 2005 ASHRAE Handbook on Fundamentals, please see the marked lines of attached exhibit Z. ASHRAE says " Pressurizing all levels uniformly has little effect on the pressure differences across floors and vertical shaft enclosures". They are inferring that pressurized floors will NOT solve any problems. Maybe this is why NO ONE has attempted to control the floor-to-floor "pressures" by "comparing" them, as I claim. ASHRAE goes on to say "Pressurizing the ground level is often used in tall buildings to reduce stack pressures across entries" This is just SIMPLY treating the SYMPTOM of a building wide "pressure" imbalance, that is preventing entry doors from "opening" or "closing" properly. This is the ONLY, SINGLE, FLOOR that ASHRAE says should be purposefully pressurized. This is why they say that ONLY a SINGLE "interior pressure sensor is required". They NEVER then say that this floor should then be compared to ANY OTHER FLOOR, but instead, ONLY TO OUTDOORS.

More important MISCONCEPTIONS are contained on this same ASHRAE page, when they say, "If mechanically supplied outdoor air is provided uniformly to each story, the change in the exterior wall pressure difference pattern is uniform". ASHRAE has taken a "STATIC" view, of a dramatically "DYNAMIC" situation. This is simply WRONG. ASHRAE is INCORRECTLY assuming that ALL of the OTHER "pressure" influences on the exterior walls and between the various floors, remain the SAME, regardless of the number of floors, or the height to the building, or changes in wind velocity, or surrounding structures By these words, ASHRAE is asserting that the air being "infiltrated" and "exfiltrated" from ALL of the floors, even the

upper floors, somehow, MYSTERIOUSLY, STAYS THE SAME, FOREVER, ONCE, "some undetermined" amount of "outdoor air" is mechanically supplied to the floors "uniformly". No wonder they didn't bother to think about, measuring, or controlling, the floor-to-floor "pressure" relationships.

My research PROVES that the "pressure" influences on the exterior walls changes DRAMATICALLY, SECOND BY SECOND, FROM FLOOR TO FLOOR, AND FROM A PART OF A FLOOR TO ANOTHER PART OF THE SAME FLOOR. I ALSO "LEARNED" THAT THIS "PRESSURE" INFLUENCE WILL BE TRANSMITTED TO **ALL** OF THE OTHER FLOORS OF MULTIPLE FLOOR BUILDINGS, THEREBY GENERATING A TRULY 'DYNAMIC' SITUATION THAT CAN **ONLY** BE CONTROLLED SECOND BY SECOND, AND INDIVIDUAL FLOOR BY INDIVIDUAL FLOOR, as I claim. ASHRAE's SIMPLISTIC SOLUTIONS ARE COMPLETE FAILURES.

Mr. Lstiburek, BELIEVED ASHRAE's above statement, per the marked lines on attached exhibit F and his figure 7. Further proof that he is a good ASHRAE 'company' man, that stays within the ASHRAE 'box'. This is also further PROOF that NO ONE COMPLETELY UNDERSTOOD THE TRUE PROBLEM, SO THEY ARE ALL JUST TREATING "SYMPTOMS" OF THE REAL PROBLEM. NO wonder there are 634,000 articles linking poor indoor air quality with "building pressure" problems. ASHRAE's, LIMITED and INCORRECT view of "building pressure" LIMITED EVERYONE BUT ME, from seeing the TRUE CAUSE and then the TRUE CURE, for ALL "building pressure" problems.

ASHRAE and Mr. Lstiburek are just more examples of EXACTLY what ALL before me have done, and they have ALL, FAILED, EVERY TIME, to accurately determine/measure/read the actual, real time, "internal"

pressure of a building "with multiple floors". ALL of these types of systems must actually "wait" until the ENTIRE, MULTIPLE FLOOR, building "inflates" or "deflates", as the various floors "transmit" their EVER CHANGING "pressure influence" THROUGHOUT the building. BEFORE, they can "see" a change in actual "internal" building pressure, and then react to it.

Their normal time to response, using this "comparison" scheme to outdoors on a multiple floor building, is approximately 600 seconds, due to the delay in building "inflation" and "deflation". My ideas concerning "dynamic" pressure sensors, as claimed in this patent at hand, allow me to respond to ANY and ALL changes in "internal building pressure", EVERY TWO TENTHS, OF EVERY SECOND, OF EVERY HOUR, OF EVERY DAY, OF EVERY YEAR. This makes me approximately 3,000 times faster that ANYONE before me. This simple FACT alone, allows me to be the FIRST, to be able to actually "see/measure", respond to and continuously correct for, ANY change in "internal building pressure", AS IT IS ACTUALLY OCCURING.

By utilizing standard pressure sensors in a "floor-to-floor comparison scheme", as I am also claiming in this patent at hand, my response time will be approximately 10 seconds, "for a floor", and the SAME 10 seconds for a "portion of a floor", and the SAME 10 seconds for the "building as a whole". My delay is much shorter than those before me, because I only have to "wait" for JUST A SINGLE FLOOR to "inflate" or "deflate". This makes me approximately 60 times faster than the CURRENT, ASHRAE, SINGLE 'internal' building pressure sensor scheme.

ASHRAE's approximately 600 second comparison scheme for multiple floor buildings, DOOMS, ALL those before me to attempting to correct an INITIAL "internal" building pressure challenge, that has already

CHANGED, BEFORE, they EVER had ANY way of knowing of that INITIAL challenge. OR IT'S SIZE. Because their ideas are so SLOW. Their "delay" is a DIRECT result of having to "wait" until the air reaches some form of "equilibrium" within the building vessel. NONE of my granted patents, NOR this patent at hand suffer from this same "delay".

ALL of these OTHER schemes eventually end up creating pressure "waves" and challenges within the building, which they must then attempt to overcome, 600 seconds later. They eventually create as many "internal" building pressure problems and challenges, as they are TRYING to solve. They ALL in FACT, become "cats chasing their own tails", and TOTALLY FAIL to achieve accurate, real time, "internal" building pressure control. Most other suppliers in the Building Pressure Control Industry, have gone on to even longer response times, of ONE HOUR or MORE, in a FAILED attempt to stop the very pressure "waves", that they themselves, are creating

I am the ONLY person attempting to patent internal building pressure measurement and control systems, CURRENTLY operating at TWO TENTHS OF A SECOND to 10 SECONDS. So, ONLY my systems can react to actual, real time changes in "internal" building pressure. To react this fast, I am extremely concerned and interested in "choosing from a group of pressures including: per wall, per floor, per wall of a floor and for the building as a whole". ASHRAE, NEVER, ONCE, mentions measuring the "pressure" of the various "floors", in their Standards or Handbooks, much less "a particular floor", or the "wall of a particular floor", or "a portion of a floor".

Plus, ASHRAE, NEVER mentions "providing at least one pressure

sensor on at least two of said multiple floors"; NOR did Applicant EVER find ANY words similar to "connecting to the pressure sensors"; and NEVER a SINGLE reference to "attaching an analyzer to said pressure sensors for receiving input from said pressure sensors and comparing at least one pressure reading from one floor with another pressure reading from at least one of the other multiple floors of said building", as I claim. Please show me a single sentence in one of these ASHRAE Handbooks that refutes my assertion.

This is unequivocal PROOF that all before me, have either MISTAKENLY thought that the "internal" areas of buildings resided at a UNIFORM pressure, NATURALLY, regardless of the number of floors involved. Or, their misconceptions of the problems associated with "internal" building pressure, left them unable to determine a solution, as I state on page 2, lines 15-21, plus page 3, lines 1-6, in my application. Along with the paragraphs that I added to the "BACKGROUND OF THE INVENTION". They are ALL WRONG. Mr. Lstiburek and ALL of these Handbooks and the included statements by ASHRAE, come from the work of committees of experts in the field of "pressure", published AFTER I filed the patent at hand. In fact, as of TODAY, ASHRAE still ONLY says that a SINGLE "internal" building pressure sensor, is ALL that is required.

If ANYONE were going to call for more than a SINGLE "internal" building pressure sensor, it would have been the "experts" of ASHRAE. I know all about ASHRAE, I **was** an ASHRAE member for twenty something years and I have been on two of these ASHRAE Standards Committees, that wrote parts of these ASHRAE's Handbooks, "Environmental Health" for three years and "Dehumidification" for two years. I have spoke at four different ASHRAE National Meetings on many topics, including "building

pressure control". I hereby declare that I have NEVER been involved in ANY ASHRAE Standards Committee, or ANY ASHRAE Committee of ANY kind, concerning "BUILDING PRESSURE", or an "INTERNAL BUILDING PRESSURE APPARATUS AND METHOD", or ANY kind, shape or form.

I have been in the "building pressure control" business for the past 28 YEARS and I hereby declare that I have NEVER seen ANYONE else monitor, or measure, the pressure of one floor and then compare it to ANY pressure of another floor, much less use the information gathered to control/regulate the pressure of one floor against the pressure of another floor. I hereby declare that I discovered how valuable a tool this would be on October 22, 2002, while reviewing data from a Ciba Specialty project in McIntosh, Alabama, involving humidity control and my patented "building pressure measurement" systems. I originally thought that measuring the "dynamic pressure" as it passed through the "skin" of a building, was ALL that was needed. But in 2002, I "learned" the NEW, NOVEL and NON OBVIOUS, ideas taught by this patent at hand.

I researched this issue for the next SIX MONTHS and found NO ONE else teaching it. I filed this patent at hand within the one year statutory period, beginning on October 22, 2002 I hereby declare that I lost most of my research data when two walls were blown out of my office building at 400 Gulf Breeze Parkway, Suite 206, Gulf Breeze, Florida, during hurricane IVAN on September 15, 2004.

I even spent valuable time and money to personally travel to TSI, INC. in Minneapolis, Minnesota in April of 2003 to ask them face-to-face, if they had ever monitored or measured the pressure of one floor and then compared it to the pressure of another floor, and if they had ever used

the information gathered to control/regulate the pressure of one floor against the pressure of another floor, using this comparison scheme. There were five of their top people in this meeting and the unanimous reply was NEVER.

TSI is the company that currently manufacturers "building pressure measurement" systems that implement the ideas taught by my granted United States patents TSI, is in my opinion, the absolute best pressure sensor manufacturer in the World, with their elegant thermal anemometer device and digital control network.

I feel the second best pressure sensor manufacturer in the World is Tek-Air Systems, Inc., in Danbury, Connecticut, with their "vortex shedding" device. In June of 2003, I spent more valuable time and money to personally travel to Tek-Air Systems. I made this trip in my Cobra convertible (which I also lost to hurricane IVAN) with a personal friend, Mr. Victor Neuman, P. E., (619-865-8235) a Cambridge educated Mechanical Engineer, who has patiently listened to all my "pressure measurement and control" theories, over the years. Victor is a very active ASHRAE member and on several of their Standards Committees Victor has been very involved in the design of Laboratory projects that involved "building pressure control", and spoke many times at ASHRAE National Meetings.

I asked three of Tech-Air's top people and Mr. Neuman, along with another Tech-Air regional employee, Paul Pinkston, that formally worked in Air Monitor's "building pressure measurement" division, linked in on a hands free phone connection, person-to-person, if they had ever monitored or measured the pressure of one floor and then compared it to the pressure of another floor, and if they had ever used the information

gathered to then control/regulate the pressure of one floor against the pressure of another floor, using this comparison scheme. The unanimous reply was NEVER. They all thought it was a good idea.

This is further proof that there is NO CURRENT "STATE OF THE ART", concerning the patent at hand. All of the above can be proven with receipts and the direct testimony of those involved.

The correct answer is that to accurately measure the "internal" pressure of a building, an "internal" pressure sensor is required on at least two floors, of multiple floor buildings, and then "COMPARED", as claimed by the Applicant, in the patent at hand. This SIMPLE FACT separates me from ALL before me and is the definitive proof that my ideas are NEW, NOVEL and NON OBVIOUS.

As further proof that my ideas are new, novel and non obvious, is my discovery that approximately three to seven percent of a building's volume, in outdoor air, MUST be introduced EVERY MINUTE OF EVERY DAY (CFM) into a building, to pressurize it to just a 0.01 inch water gauge "positive" pressure, and ten to seventeen percent to accomplish a 0.10 inch "positive" pressure The existing ASHRAE recommendation is to introduce just ten percent more outdoor air into a building, than is being exhausted. This was an extremely naive decision by ASHRAE, and I personally cannot imagine how they chose this number I find NO basis in reality, or volumetric mathematics, that supports it. My research and practical application have proven it TOTALLY WRONG.

My research has shown that ALL "standard" air conditioning, heating and ventilation units MUST be able to handle up to 75% outdoor air and 25% return air, and produce a 52°F dewpoint/55°F dry bulb, supply

air temperature, even in the hottest and most humid climates, if they are to be used to adequately "pressurize" buildings and prevent mold and mildew in the building's "skin" Currently, Trane, Carrier, McQuay, etc.... build ALL of their "standard" air conditioning, heating and ventilation units to ASHRAE Energy and Performance Standards that ONLY allow them to handle around 20% outdoor air, or LESS in humid climates. So, my ideas as taught will require that ALL air conditioning manufacturers "retool" to handle these NEW, INCREASED, outdoor air requirements. This MAJOR change alone will require years to implement. ASHRAE's, additional 10% outdoor air rule, has resulted in DEFORMING the performance of an ENTIRE Industry.

Plus, it will be fairly easy to adapt my pressure sensors and control systems to existing buildings and their existing control systems, I have already done this with Johnson and Honeywell. But it most cases, it will be EXTREMELY difficult to modify the building's air conditioning system and duct system, to allow accurate "building pressure control". Again, years of the practical application of ASHRAE "MINIMUM" recommendations, have made it EXTREMELY difficult, if not IMPOSSIBLE, to modify existing buildings to allow practical and accurate "building pressure control". Smaller buildings and stand alone Military structures can more easily be adapted. I have designed and installed over 20 systems in existing Chemical Plant, stand alone buildings. But in all HONESTY, most buildings will be extremely difficult to modify. Requiring an EXTREME commitment from ASHRAE and it's associated Industry, that I personally do NOT see occurring.

Buildings that introduce the quantities of properly conditioned outdoor air that I recommend, will have FAR SUPERIOR INDOOR AIR QUALITY and experience DRAMATICALLY REDUCED spreads of mold, mildew and contagious diseases (SARS, BIRD FLU, EVEN THE COMMON

COLD, etc...), than buildings that have applied the ASHRAE "MINIMUM" Outdoor Air Standards. ESPECIALLY HOSPITALS. By SIMPLY pulling the required outdoor air from 75+ FEET above the ground (I used EPA data to determine this height), I assert that ONLY the ideas that I teach, could protect EVERYONE, in EVERY commercial building, in America, from a Chemical, Biological and Radiological (dirty bomb) attack. But I see an ENTIRE Industry heading in the WRONG DIRECTION. I ask WHY are we designing EVERY building we LIVE in and WORK in, to ASHRAE "MINIMUM" Standards. Some of which are based on WRONG assumptions. So, I personally may NEVER make much money from all my Patent work and research, and all the while, America remains vulnerable to attack.

It is for these reasons and more, which the ideas expressed and claimed in this and ALL of my patents, are NEW, NOVEL and NON OBVIOUS and should be granted. Please feel free to contact me with any questions concerning this letter or any other questions that arise.

Applicant respectfully request that this patent be granted, as submitted.

Respectfully submitted,

Dated: 5/10/2006 By: J. Patrick Fex, Jr.

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I hereby certify that this correspondence is being transmitted to the Patent and Trademark Office facsimile number (571) 273-8300 on 10, May, 2006. Number of Pages including Transmittal Letter and Exhibits, 90 pages.

J. Patrick Fex, Jr. J. Patrick Fex

63

A

Air Pressure and Building Envelopes

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Abstract

Control of air pressure is key to several important performance aspects of the building system. Air carries moisture which impacts a materials long-term performance (serviceability) and structural integrity (durability), behavior in fire (smoke spread), indoor air quality (distribution of pollutants and microbial reservoirs) and thermal energy.

Understanding the significance of the complex flow and pressure distribution problems created by the interaction of the building envelope with the mechanical system and climate can lead to changes in building design, commissioning, operations, maintenance, diagnostics and rehabilitation.

1. Introduction

Understanding the significance of the complex flow and pressure distribution problems created by the interaction of the building envelope with the mechanical system and climate can lead to changes in building design, commissioning, operations, maintenance, diagnostics and rehabilitation.

Diagnostic protocols can be based on the enhanced understanding of pressures and air flows in buildings and the measurement techniques presented in this thesis. These diagnostic protocols can be used to aid in identifying problems in buildings related to indoor air quality, smoke and fire spread, durability of the building envelope relating to air transport of moisture, operating costs relating to energy use, and comfort issues related to humidity, temperature and odors.

Additionally, rehabilitation approaches can also be developed that allow an assessment of the existing interactions in buildings to be rehabilitated, provide the designer with choices as to desired interactions given the constraints of the existing building, give the commissioning agent performance guidelines to compare against after rehabilitation is complete and provide the building operators with building operating instructions and required operating air pressure relationships.

The designer can now have a choice to either prevent accidental coupling of the mechanical system to the building envelope by design changes to the building envelope and the mechanical system or to deliberately couple the mechanical system to the building envelope to provide enhanced control of air transported moisture control, odor control, smoke control or heat transfer control.

The commissioning agent can now have the ability to determine the interactions of the building envelope and the mechanical system in a systematic, repeatable manner and compare the interactions to design intent.

Finally, the building operators can now have the ability to determine the interactions of the building envelope and the mechanical system on an ongoing basis in a systematic,

(B)

micromanometer indicated that the classroom was operating at 4 Pascal's negative with respect to the crawl space (Figure 1). Furthermore, interior wall cavities were found to operate at 1 Pascal negative with respect to the classroom.

Removal of deteriorated plaster revealed the wall construction. Interior plaster was installed over wood furring strips creating an air space (or channels) between the plaster and the masonry wall. Removal of ceiling tiles indicated that the plaster finish extended just above the dropped ceiling level and that the air space (or channels) between the plaster and the masonry wall was open at the top and connected to the air space above the dropped ceiling. This wall geometry created "chimneys" which extended from the crawl space to the air space above the dropped ceiling.

The air space above the dropped ceiling was used as a return air plenum that operated under a negative air pressure relative to the classroom due to the operation of air handling units within the dropped ceiling (Figure 2). Additionally, each classroom was equipped with a roof top exhaust fan that extracted air from the dropped ceiling depressurizing both the dropped ceiling and the classroom relative to the exterior. When the roof top exhaust fan was shut down, the negative air pressure difference between the classroom and the crawl space was reduced to less than 1 Pascal.

Discussion with school district staff, and photographs indicated that no ground cover was present in the crawl space. According to staff, the top surface of the soil appeared dry. In addition, many of the steam lines in the crawl space were reported to be uninsulated due to ongoing asbestos mitigation work. Crawl space temperatures in excess of 30 degrees C. were typical according to staff.

Crawl space vents were sealed and an exhaust fan was installed in the crawl space exhausting air to the exterior. The access opening connecting the affected crawl space and the adjacent crawl space was also sealed. Air pressure differentials between the affected classroom and the crawl space were monitored. Extracting approximately 325 L/s of air from the crawl space by means of an exhaust fan depressurized the crawl space 4 Pascal's with respect to the classroom area. This was shown to result in a flow reversal of air between the crawl space and the classroom area. Using a smoke pencil air could be shown to flow from the classroom area into the crawl space when the exhaust fan was operating rather than from the crawl space into the classroom.

Conclusions

The complaints from the teacher and students were due to musty odors resulting from the deterioration of wood trim and other building materials. These odors and deterioration were due to excessive moisture migrating from the crawl space under the classrooms into the interstitial spaces of interior and exterior walls as a result of the air pressure relationship between these spaces and the crawl space.

The rationale for these conclusions follows.

For an odor or indoor air quality problem to occur, four factors are necessary:

- Pollutants are necessary;
- People (receptors) are necessary;
- Pathways are necessary (connecting the pollutants to the people); and
- Pressure differences are necessary (to push or pull the pollutants down the pathways to the people).

C

It is obvious that people are necessary to be present in order for a problem to be detected, or for a problem to exist. It is clear that although removing occupants is an effective short term solution, this strategy is not an appropriate long term solution. The receptors in this case are the teacher and students.

A pollutant is also necessary. In this case the primary pollutant is moisture, and this moisture pollutant leads to the creation of the secondary pollutants which are mold and other biological agents. Eliminating (removing) the pollutant (source control) is a very effective approach to controlling indoor air quality problems.

A pathway connecting the pollutant and people (receptors) is also necessary. If pollutants and receptors are isolated from each other by "perfect" barriers, then problems can also be eliminated. In this case the pathway connecting the moisture pollutant and the receptor are the openings connecting the crawl space and the channels between the plaster surfaces and the masonry walls.

Finally, a driving force is required to "push" or "pull" the pollutant down the pathway to the occupants (receptors). In this case the driving force is an air pressure difference between the crawl space and the classrooms. This air pressure difference is created by a combination of the operation of the roof top exhaust fans and the operation of the air handling units within the dropped ceiling areas.

Moisture (the primary pollutant) in the soil in the crawl space is evaporated due to the elevated temperatures in the crawl space. Warm moisture saturated air migrates through openings in the floor slab into the air space created by the plaster and wood furring (the pathway). The air is pulled into the air space between the plaster and wood furring as a result of the operation of the roof top exhaust fans and the operation of the air handling units (the pressure "drivers"). The moisture saturated air cools once it is in the furring space leading to condensation and saturation of the building materials at this location. The saturation of the building materials leads to their deterioration and the creation of odors and other biological agents (the secondary pollutants). These secondary pollutants enter the classroom and come in contact with the teacher and students (the receptors).

The dry crawl space soil surface observed is dry due to the rapid rate of evaporation of moisture (vapor diffusion) from the upper surface of the crawl space soil surface into the crawl space enclosure due to the heat from the uninsulated steam lines, resulting in the upper surfaces appearing dry. Where it was possible to probe several inches beneath the crawl space floor surface, the ground material was damp to the touch.

Ventilation as a moisture removal mechanism was present in the crawl space by virtue of the fact that crawl space vents were present and that the ambient (exterior) vapor pressure was lower than the crawl space enclosure vapor pressures. However, the rate of moisture removal by ventilation was extremely low due to the small number of vents, their location and small cross sectional areas.

Moisture levels within enclosures are determined by a combination of moisture source strength (rate of moisture generation or entry) and air change or ventilation (rate of moisture removal). If the rate of moisture generation or entry is higher than the rate of moisture removal then high enclosure moisture levels can occur. The crawl space airborne moisture levels were high. These crawl space airborne moisture levels were high because the rate of moisture generation or entry in the crawl spaces is high compared to the rate of moisture removal by ventilation.

Rehabilitation Measures

D

The rehabilitation measures involved the four factors active in air quality and odor problems (people, pollutants, pathways and pressures).

In the short term, the receptors were removed. Students and teachers were not allowed access to the affected classrooms until the rehabilitation measures were implemented.

Source control for the primary and secondary pollutants was undertaken. The secondary pollutants were removed by stripping the damaged portions of the interior plaster surfaces and removing all wood baseboard trim. The carpets were discarded.

The primary pollutant, airborne moisture from the crawl space, was controlled at the source. Crawl space enclosure moisture levels can be reduced only two ways, by limiting moisture source strength (moisture entry) or by dilution (moisture removal by ventilation or dehumidification). A desired result is where the rate of moisture entry is lower than the rate of moisture removal, or where moisture accumulation in building materials does lead to deterioration. In order to achieve this desired result, the control the source strength (moisture entry by evaporation from the ground) was selected rather than dilution (moisture removal by ventilation).

A temporary polyethylene ground cover was installed immediately. A permanent stabilized, reinforced polyethylene ground cover was subsequently installed after mechanical system work was completed in the crawl space (Figure 3). As part of this work, all steam lines were re-insulated.

The pathway for the primary pollutant (moisture) was sealed by installation of foam sealants after damaged and deteriorated materials were removed at baseboard locations.

Finally, the driving force for pollutant transfer, specifically the air pressure relationship between the crawl space and the classrooms, was altered by the installation and operation of an exhaust fan (Figure 4). This exhaust fan runs continuously. In order to facilitate air pressure control the crawl space vent openings were permanently closed. Crawl space perimeter walls were insulated creating a conditioned crawl space that is permanently maintained at a slight negative pressure with respect to the classrooms via the operation of the crawl space exhaust fan.

3. Smoke and Fire Spread

A hotel located in Tallahasee, FL provides a good example of addressing smoke and fire spread concerns in an existing facility scheduled for renovation by using pressurization testing and pressure field measurements.

Description of Facility and History of Problems

The facility is a seven story concrete frame building constructed on a concrete grade beam/slab foundation. The ground level contains the hotel registration area, restaurant, meeting rooms, and service areas. The remaining upper six floors contain hotel suites. There are 15 suites per floor or 90 suites in total. Each suite contains a hotel room and a bathroom containing a bathtub/shower, vanity and toilet.

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The exterior infill walls are steel stud with interior and exterior gypsum sheathing. The exterior cladding is a traditional hardcoat stucco system over building paper. The stud cavities are insulated with kraft faced fiberglass batt insulation. The interior surfaces are finished with a vinyl wall covering.

According to design drawings roof top exhaust fans extract 25 L/s from each suite at bathrooms (Figure 5). Additionally, 100 L/s is extracted from each corridor. In other words, 475 L/s is extracted from each floor. Total exhaust for the six floors containing suites is 2,850 L/s. The roof top exhaust fans operate continuously.

Each suite contains a through-wall packaged terminal heat pump (PTHP) for space conditioning. Each PTHP supplies 30 L/s of outside air when it is operating. An additional PTHP also serves each corridor suppling an additional 100 L/s to the corridors. Approximately 550 L/s of outside air is supplied to each floor when all the PTHP's on a floor are operating.

The facility has been experiencing persistent high humidity problems since it was constructed 5 years earlier. Additionally, it has been scheduled for a major renovation where interior rooms are to be refurbished. As part of the renovation, a smoke pressurization and smoke extraction system are to be installed.

Investigation and Testing

Digital manometers were used to establish the air pressure relationships throughout the facility. Air pressure measurements were taken during calm weather in April. Exterior temperatures were approximately 27 degrees C. Interior temperatures were approximately 24 degrees C. The facility in general was found to be operating at between 3 and 5 Pascal's negative with respect to the exterior. The facility was most negative at the upper floors. Flow hood measurements of flow through exhaust grills in suites in upper floors indicated greater exhaust flow than similar measurements in lower floors. The air pressure driver was the roof top exhaust fans. When roof top fans were shut down, the hotel suite floors became slightly positive with respect to the exterior - approximately 1 to 2 Pascals. Most, but not all PTHP's, were shut down during the time that roof top exhaust fans were shut down.

The typical duty cycle of individual PTHP units was found to be about 20 percent. It was estimated that only three suite PTHP's plus the corridor PTHP operate at any one time per floor supplying only approximately 190 L/s of outside air per floor. This yields a deficit of supply to exhaust of approximately 285 L/s per floor.

Leakage testing of individual floors was conducted using variable speed pressurization fans. Two types of measurements were taken. The first involved pressurizing an individual floor by extracting air from a stairwell whose exterior doors were opened to the exterior. The floors above and below the floor being tested were maintained at exterior pressure by opening all windows and corridor doors. The second type of measurement involved pressurizing the floors above and below the test floor as well as the elevator shafts to identical pressures to the test floor thereby providing isolation of test floor leakage to floors above and below. The experimental set-up is presented in Figure 6.

During both types of testing the individual bathroom exhaust grills and supply air PTHP registers were taped shut. Additionally, hallway supply air grills were also sealed. Under the first approach, approximately 500 L/s of outside air was required to pressurize

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individual floors 5 Pascal's to the exterior. Under the second approach, approximately 275 L/s of outside air was required to pressurize individual floors 5 Pascal's to the exterior.

Air pressure measurements within interior partition walls were also taken with portable digital micromanometers. Walls connected to the service shafts containing the exhaust ducts were found to operate 1 to 2 Pascal negative with respect to interior rooms. Walls not connected to service shafts appeared to operate at the same pressure as interior rooms. When individual roof top exhaust fans servicing a particular service shaft were shut down, wall cavity pressure differences relative to interior rooms disappeared.

Wall coverings were removed at select locations from interior partition walls. Additionally, access openings were cut through gypsum board to allow inspection of wall cavities. Vinyl wall coverings were found to be discolored with pink spots on room side surfaces and discolored with black spots on gypsum side surfaces. Both types of discoloration were more severe on interior partition walls connected to service shafts. Mold growth was found within wall cavities. Again, as with the case of the wall coverings, more growth was found within wall cavities connected to service shafts than wall cavities not connected to service shafts.

Conclusions

The deficit of exhaust to supply air flow is responsible for the negative air pressure within the facility. The negative air pressure causes the infiltration of exterior unconditioned air. This unconditioned air is responsible for the high interior humidity except during the winter months when the exterior air has a low moisture content. Additionally, the negative pressure field developed in interior partition walls connected to service shafts is due to leakage of exhaust ductwork contained within the service shafts. This negative pressure field causes the infiltration of exterior unconditioned air into the interior wall cavities leading to mold growth and discoloration of the interior vinyl wall coverings.

Rehabilitation Measures

A supply air system was designed to pressurize the hotel suite floors. The key features of this system follow:

- In order to achieve pressurization, the existing supply air vents in each PTHP unit are permanently closed.
- Two roof top units supplying 2,100 L/s of neutral temperature air at approximately 50 percent relative humidity are used to supply 700 L/s of air to each floor (Figure 7).
- The existing exhaust system is balanced to extract 475 L/s from each floor.
- The supply excess of approximately 225 L/s per floor pressurizes each floor approximately 2 Pascal's relative to the exterior.
- A grill is installed between the corridors and each service shaft at each floor to allow the extension of the corridor air pressure field into the service shafts at each floor thereby eliminating the previous negative pressure field that extended from the service shafts within interior partition walls to the exterior (Figure 8).

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The existing vinyl wall coverings were removed and decontamination of the mold occurred. Vapor permeable interior finishes were specified to replace the impermeable vinyl wall coverings.

A smoke pressurization and smoke extraction system was also designed using the pressurization test results (Figure 9). A minimum 25 Pascal pressure difference between fire floors and non fire floors was specified as a design criteria. Approximately 1000 L/s was found to pressurize each floor approximately 25 Pascal's relative to the exterior when the roof top exhaust fans are not operating. Conversely, an approximate exhaust flow of 1,000 L/s was found to depressurize each floor 25 Pascal's relative to the exterior when the corridor supply system is not operating. By supplying 1,000 L/s to non fire floors and extracting 1,000 L/s from fire floors when the supply and exhaust systems are de-energized a greater than 25 Pascal pressure difference can be maintained.

4. Durability (moisture)

A data processing center located in Hartford, CT provides a good example of addressing durability (moisture) concerns in an existing facility by using "pressure mapping" to diagnose the problems (identify the linkage among the constituent building pressure fields) and by using temperature controlled pressurization of interstitial cavities to remediate the facility.

Description of Facility and History of Problems

The facility is a 10,000 m2 two story steel framed structure on a concrete slab supported by a grade beam foundation. The exterior cladding consists of face sealed precast panels. Insulated steel stud walls are constructed to the interior of the precast panels. A cavity varying between 50 mm and 500 mm exists between the interior surfaces of the precast panels and the exterior face of the insulated steel stud walls. Gypsum board is installed on the interior of the steel stud walls over a polyethylene air-vapor barrier.

The roof assembly is a built up roof over 100 mm of rigid insulation installed over a concrete roof deck.

The facility contains raised floor plenums that provide conditioned air throughout. The conditioned air is heated, cooled, humdified, dehumidified as necessary by floor mounted conditioning units that supply air to the under floor plenums. Outdoor air is preconditioned and introduced to each floor by roof mounted air handlers.

The space conditioning and outdoor air systems (Figure 10) create a pressurized enclosure that is maintained at 24 degrees C., 50 percent relative humidity year round.

Condensation during winter months occurs on the inside face of the precast panels and drains out at floor slabs and window penetrations leading to deterioration of interior finishes, mold odors and microbial contamination of interstitial cavities.

Investigation and Testing

Air pressure differential measurements of the facility and interstitial cavities ("pressure mapping" of the facility) were taken when exterior temperatures were approximately 15 degrees C. Wind conditions were dead calm. The air pressure differential relationships as measured are presented in Figure 11.

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Four portable variable speed calibrated flow fans ("blower doors") were used to introduce outside air to the interstitial space between the precast panels and the insulated steel stud walls. The fans were positioned at the four exterior corners of the building and introduced air into the interstitial spaces via access holes that were cut in soffits over exterior doors. Approximately 4,000 L/s of outside air was necessary to pressurize the interstitial spaces 5 Pascal's relative to the interior space above the raised floors (the occupied space).

Conclusions

The pressurization of both the occupied space and the area under the raised floors leads to the exfiltration of interior moisture laden air into the interstitial cavities between the precast panels and the interior insulated steel stud walls.

Condensation on the cavity side of the precast panels occurs whenever the exterior temperature drops approximately 5 degrees C below the dew point temperature of the interior air/vapor mix. Based on interior conditions, the exterior temperature at which condensation typically occurs is approximately 10 degrees C.

The precast panels are significantly tighter than the interior insulated steel stud wall assembly as can be seen by examining the ratio of air pressures across the assemblies (approximately 80 percent of the air pressure drop across the exterior wall assembly occurs across the precast panels). The rate of moisture entry into the wall cavities via air flow is greater than the rate of moisture removal by air flow.

The original design of the wall assembly should have provided for back venting of the precast panels coupled with drainage of the interstitial cavities to the exterior. A drainage plane system for rain control should have been provided on the exterior of the insulated steel stud wall assembly.

It is not practical as a retrofit measure to tighten the interior insulated steel stud wall such that it becomes significantly tighter than the exterior precast panels. Conversely, it is not possible to introduce drainage and ventilation to the exterior precast panel system without removing the panel system and incurring an enormous cost.

Rehabilitation Measures

A cavity pressurization system was designed (Figure 12) that introduces outside air to pressurize the interstitial space between the precast panels and the interior insulated steel stud wall system. The outside air is introduced at the roof top via 4 variable speed fans that can introduce up to 2,000 L/s of outside air each. The fans are connected to the building automation system. The building automation system monitors the air pressure difference between the interior occupied space and the interstitial cavity as well as the exterior temperature. When the exterior temperature drops below 10 degrees C, the interstitial cavity is pressurized approximately 5 Pascal's relative to the interior occupied space using exterior air. (SAME FLOOR)

A buffer air space is provided at the perimeter of the raised floor plenum system by the installation of a baffle and floor grilles. In this manner the high positive air pressure field existing in the under floor plenum is prevented from extending to the exterior wall.

The variable speed fans allow compensation for stack effect pressures during cold weather. Using the pressure difference between the interior occupied space and the

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interstitial cavity as a reference pressure difference compensates for the dynamic effects of wind allowing the building itself to act as a "dash pot". Using the exterior air pressure as a reference pressure is impractical due to the high variability of the boundary layer air pressure regime.

5. Comfort

A condominium development located in Mahwah, NJ provides a good example of addressing comfort concerns using pressurization testing and series air pressure differential measurements to diagnose building related problems.

Description of Facility & History of Problems

The development in question is multi-unit project constructed between 1990 and 1991. The units are multi story wood framed structures. Floor framing consist of open webbed floor trusses. Party walls are double wood frame with fire rated gypsum.

The space conditioning systems consist of forced air natural gas units. These units are located in utility rooms. A natural gas water heater is also located within each utility room. Meter closets are constructed external to the units.

The residents of some of the suites had been complaining of cold interior floor temperatures, high heating bills, an inability to heat the units, large temperature differences between rooms, between upper floors and lower floors, frozen pipes, and water leakage from ice damming.

Investigation and Testing

The interior structure of the buildings was visually examined from within via existing access openings, from within the attic spaces and from access openings (intrusive disassembly) cut in interior gypsum board and through wood subfloor sheathing. Particular attention was focused on utility chaseways, fireplace chaseways and enclosures, party wall construction, floor framing, bulkheads, service penetrations, the intersection of sloped ceilings and partition walls and mechanical system installation.

Visual observations from within attic spaces of roof assembly perimeters indicated insulation substantially filling the majority of the spaces between the underside of roof sheathing and the top plates of exterior walls. Insulation vent baffles were intermittently installed in truss bays. Soffit venting was discontinuous. Soffit venting, where installed, occurred through the use of perforated soffit closures.

In roof regions which experienced the greatest amount of ice damming, specifically the lower reaches of valleys at the intersection of two different roof slopes, no provision for roof ventilation was found. Intersecting roof truss cavities were blocked solid with wood framing and filled with insulation.

Attic temperatures were measured in the range of 5 to 10 degrees C. when the exterior temperature was - 18 degrees C. indicating a combination of substantial heat loss and a likely lack of effective attic ventilation. Large gaps were observed between openings cut in ceiling gypsum board and boots connected to supply ductwork installed in attics penetrating the ceiling gypsum board openings. Voids and gaps were observed between ceiling gypsum board and the underside of attic ceiling batt insulation.

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Air pressure measurements indicated significant changes in air pressure relationships within the floor interstitial/plenum spaces when furnace fans operated. Floor spaces tended to go to both positive and negative up to 3 Pascals relative to the exterior and relative to the conditioned space on a random (unit-per-unit) basis when the air handlers operated indicating substantial supply or return duct leakage.

Interaction of Building Envelope Air Leakage and Mechanical System Leakage

The leakage of the duct system when the air handlers are operating induces higher than typical driving forces across the building envelope. Furthermore, the construction and communication of the interstitial cavities, the fireplace chaseways, the party walls, and the attic spaces lead to stack effect air pressure driving forces in addition to the air handler induced air pressures. When stack effect air pressure differentials are combined with duct leakage/air handler induced air pressure differentials as well as wind induced air pressure differences the combined driving forces and identified air leakage sites account for the significant building envelope air leakage which occurred and resultant complaints and problems.

When wind blows over a building, the exterior of the windward side of the building experiences a positive air pressure, and the exterior of the leeward side experiences a negative air pressure. Side walls typically experience negative air pressures. Leakage openings in the building envelope which are exposed to these wind induced air pressure differences leak air. In general the greater the leakage areas the greater the effect of wind on total air leakage/air change.

This condominium development had significant windward, leeward and sidewall leakage areas throughout the project. These leakage areas communicated with each other across the open webbed floor system.

Additionally, large voids and chaseways extended vertically between stories, thereby creating significant stack effect air pressures and large air flows. These flows were exacerbated by the open webbed floor construction creating floor plenums which communicated with these vertical voids and chaseways (Figure 21). The most significant of the vertical chaseways were the fireplace chaseways. However, all units in all buildings were affected by vertical communication.

Conclusions

The units leaked substantial quantities of air both across the building envelope as well as from the mechanical system ductwork. The building envelope and mechanical system air leakage was the cause of the comfort complaints, high utility bills and frozen pipes at the development.

The ice damming and associated water damage occurred as a result of the ineffective ventilation of the underside of perimeter roof sheathing due to a lack of air flow pathways and/or blocked pathways coupled with excessive heat loss into the attic spaces due to air leakage from attic bypasses and leakage of heated air out of duct distribution systems particularly at boot/ceiling connections.

The leakage of the duct system when the air handlers are operating induces higher than typical driving forces across the building envelope. Furthermore, the construction and communication of the interstitial cavities, the party walls, and the attic spaces likely lead to stack effect air pressure driving forces in addition to the air handler induced air pressures.

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When stack effect air pressure differentials are combined with duct leakage/air handler induced air pressure differentials the combined driving forces and identified air leakage sites can easily account for the resultant complaints and problems.

The measurement of leakage through pressurization testing and air pressure measurements of interstitial spaces supports the hypothesis of pressure effects resulting from the air handling systems. The identification of air leakage pathways through visual observations, intrusive disassembly, and induced pressure differentials further supports the hypothesis.

In heating climates, where sufficient heat loss occurs at roof perimeters above insulated wall assemblies, ice damming can occur. The heat loss can melt snow on the roof causing melt water to run down over the roof overhang, where it can freeze forming a dam. The ice dam causes the water to back up and leak under overlapped shingles and through roof sheathing. This heat loss can occur from either a lack of thermal insulation where exterior walls intersect roof and attic assemblies, or from the leakage of warm air up and out of exterior and interior walls, attic bypasses and from duct leakage.

Air leakage from attic bypasses, exterior walls and air leakage out duct distribution systems as boot/ceiling connections resulting in high heat loss coupled with a lack of continuous venting and blocked rafter spaces at eve perimeters led to ice damming and the subsequent water damage. Observations revealed the lack of a continuous air space and perimeter eve ventilation as well as many rafter cavities blocked solid with wood framing. Temperature measurements between attic spaces and the exterior coupled with air pressure measurements and visual observations confirm the air leakage from attic bypasses, duct leakage and resultant high heat loss into the attic space.

Continuous soffit ventilation can be used to flush heat away from the underside of the roof assembly, preventing it from melting accumulated snow on the roof and thus controlling the formation of ice dams. For continuous soffit ventilation to be effective, a clear, continuous 2 inch air space should be provided at the roof eave perimeter. This is usually accomplished with carefully installed baffles at each truss bay. These baffles must be selected and installed in a manner which controls/prevents wind washing or the short circuiting of attic insulation.

In order to control ice damming it is also necessary to reduce heat loss into attic spaces. This means that air leakage from attic bypasses, interior and exterior walls as well as out of duct work needs to be reduced or eliminated. In addition, where roof geometry permits, additional thermal insulation may also be installed. However, this additional thermal insulation should not be installed at the expense of a continuous ventilated air space located above the insulation.

Rehabilitation Measures

The mechanism responsible for the ice damming and resulting water damage is ineffective ventilation of the underside of perimeter roof sheathing due to a lack of air flow pathways and excessive heat loss into the attic spaces due to air leakage from attic by passes and leakage of heated air through the building envelope and out of duct distribution systems. Therefore, addressing these factors can alleviate the ice damming complaints:

- Sealing all attic air leakage sites particularly at utility chaseways, party walls service penetrations, and the intersection of interior partition walls and sloped cathedral ceilings;

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- Sealing all boot connections penetrating attic ceiling gypsum board;
- Providing continuous soffit ventilation and a continuous 50 mm clear air space above the roof ceiling insulation at the perimeter of the roofs; and
- Providing additional vent openings at roof ridge locations.

The mechanism responsible for the comfort complaints, high utility bills and freezing pipes is building envelope and mechanical system leakage as a result of the following factors:

- Large leakage openings connected to interstitial cavities/chaseways creating substantial air leakage pathways;
- Duct leakage induced air pressure differentials; and
- Stack effect induced air pressure differentials as a result of party wall leakage areas and interior air leakage pathways;

TREATING SYMPTOMS

Therefore, addressing these factors can alleviate the comfort complaints, reduce the high utility bills and eliminate freezing pipes:

- Sealing all air leakage sites particularly at utility chaseways, party walls service penetrations, the intersection of interior partition walls and sloped cathedral ceilings, fireplace chaseways, rim joist assemblies, and the intersection of shed roofs/porch roofs and exterior walls;
- Sealing all boot connections penetrating gypsum board;
- Balancing the air distribution systems; and
- Insulating, sealing and heating the floors over garage spaces.

6. Operating Cost (energy)

A single family residence located in Las Vegas, NV provides a good example of addressing operating cost (energy) concerns by addressing duct leakage in two ways: sealing ducts or relocating the air pressure boundary. The effects of duct leakage on the building enclosure were determined by measuring the response of the interior building air pressure field to the operation of the air handling system.

Description of Facility and History of Problems

A homeowner began to complain about high utility bills. Electricity bills of over $275 per month were being reported for a 3 month period between June and the end of August.

The home is a recently constructed single family detached house, 200 square meters of floor area, one story in height over a concrete slab foundation. The exterior walls are wood framing sheathed with waferboard. The exterior cladding is painted stucco. Roof construction is wood sheathing installed over wood trusses. The roof assembly is vented in compliance with the 1:300 ratio. Interior cladding is painted gypsum board.

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The space conditioning system is a forced air high efficiency heat pump. The air handler is located in the attic. Most of the supply and return ductwork is located in the attic. Exhaust fans are installed in bathrooms. A recirculating range hood is installed in the kitchen area. A fireplace is installed in the living room with tight fitting glass doors and exterior combustion air ducted directly to the firebox.

Investigation and Testing

Visual examinations, temperature measurements along with smoke pencil and air pressure differential testing using a digital micromanometer were the principle means of investigation.

The home was visited during a cool period in mid September. Exterior temperature was measured at approximately 25 degrees C. Exterior relative humidity was measured at 50 percent. Interior temperatures were taken at several locations in various rooms in the house. Interior temperatures ranged from 22 degrees to 26 degrees C.

A smoke pencil indicated that air was being forced out of the building at living room windows when the air handler switched on, suggesting that the living room operated at a positive air pressure with respect to the exterior. Smoke pencil readings also indicated that air was exiting from most bedroom windows. This was confirmed when the digital micromanometer was used to measure interior living room and bedroom air pressures relative to the exterior. When the air handler was operating the living room would rise to 3 Pascal's positive relative to the exterior. When the air handler was not operating, the living room and the bedrooms would come to a neutral air pressure with respect to the exterior.

Air pressure measurements were repeated under various conditions of interior doors being opened and closed. Not much difference in positive pressurization was noted with the opening and closing of bedroom doors.

A slight increase in air pressure of 1.5 Pascal's occurred in the master bedroom (relative to the main body of the house) when the master bedroom door was closed. With all interior doors in either the open or closed position, the building operated under an approximate 3 Pascal positive air pressure relative to the exterior when the air handler was on.

When the air handler fan was switched on, but with the compressor not functioning, noticeably warm air was being supplied from a few of the supply registers. Discussions with the homeowner indicated that it was very difficult to cool the building during hot weather.

Conclusions

The operation of the air handler draws hot air from the attic into the return side of the air handler causing the entire building enclosure to become pressurized. When this hot air is introduced into the return side of the air conditioning system, cooling efficiencies are significantly reduced. The air conditioning load is significantly increased by the introduction of this hot air.

Air handlers create air pressure difference in buildings in several ways including duct leakage and by unbalanced air flows. In this example, return leaks appear to be dominating, as the building enclosure operates at positive air pressure with respect to the exterior when the air handler is operating.

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In this example, the effect of bedroom door closure was not substantial. Return side leakage was shown to be present by virtue of the fact that the building enclosure went to a positive air pressure when all interior doors were open and the air handler was operating. The lack of effect of bedroom door closure was demonstrated by very little change in air pressure occurring when interior doors were opened and closed.

Air in the attic is typically much hotter than the exterior air due to the effect of solar radiation. When this air is drawn into the return side of the air handling system, it is not unusual to experience a significant drop in performance. Eighty percent and greater reductions in efficiency and capacity are common. This typically manifests itself in substantially increased utility bills and comfort complaints. Houses are unable to be maintained at cool temperatures.

Rehabilitation Measures

The air pressure relationship in this building should be altered. This can be done two ways. In the first way, the return side leakage of the air handling system can be repaired. Attic bypass leakage (openings around the outside of ducts) should also be repaired as part of this strategy. The strategy can be summarized as follows:

- Seal all return leaks in ductwork and the return plenum using mastic. Seal the opening around all ducts penetrating the attic ceiling. Seal openings along top plates.
- Provide transfer grills to facilitate air flow from bedrooms to the main return grill. Pressure balance house (check air pressure relationships, avoid negative air pressure after return side leaks are repaired).

In the second way, the air pressure boundary can be relocated. Under typical conditions, the pressure boundary in a vented attic is the attic ceiling gypsum board. This typically leads to problems, such as in this example, where the duct work and air handler are located external to the pressure boundary in the vented attic. An unvented conditioned attic can be constructed where the pressure boundary becomes the roof deck (Figure 22). In this manner the pressure boundary now encloses the duct work and air handler.

Roof ventilation is sealed and thermal insulation is moved from the attic ceiling to the underside of the roof deck. Transfer grilles are installed in the attic ceiling connecting the attic space to the main level of the house. These grills equalize air pressures and facilitate the flow of air throughout the house. In this manner the attic space becomes a conditioned space. Air leaking out of the supply ducts is no longer lost to the outside. Air extracted from the attic space is no longer drawn from the outside. Additionally, the duct work and air handler are now exposed to room temperatures rather than the extreme temperatures in vented, unconditioned attic spaces.

After a building enclosure with substantial return system leaks is repaired using the first approach, supply system leaks can become the dominant effect. Supply leaks can lead to depressurization of building enclosures and serious health effects from the spillage and backdrafting of combustion appliances and mold growth from infiltration of hot, humid air into interstitial cavities in humid climates. Air pressure relationships should be retested after all repair work is completed in order to prevent the overlooking of adverse pressure effects.

6. Conclusions

In order to design and build safe, healthy, durable, comfortable and economical buildings we must understand air flow. Air flow carries moisture which impacts a materials long-term performance (serviceability) and structural integrity (durability), behavior in fire (spread of smoke), indoor air quality (distribution of pollutants and location of microbial reservoirs) and thermal energy.

The key to understanding air flow is pressure. Air pressure affects the interrelationships between mechanical systems and the building envelope. These interrelationships are significant and involve numerous disciplines including architecture, structural engineering, mechanical engineering, fire protection, acoustics, and interior design. The cross disciplinary nature of the relationships make them easy to overlook, yet these relationships must be understood to avoid costly mistakes.

The design and construction of the building envelope (the walls, roof and foundation) significantly affect the design of the heating, ventilating and air conditioning (HVAC) systems. At the same time, the design, installation and operation of the HVAC system affects condensation and moisture accumulation within building cavities, rain penetration, pollutant migration, and the durability of the building envelope.

The strategy to control air pressure in the building includes eliminating the largest openings and holes. Additionally, it includes controlling the air pressure fluctuations generated by the building mezzoclimate, indoor climate, microclimate as well as the HVAC system operational conditions. To control the air, you must first enclose the air. When you enclose the air, you must control the mechanical system.

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$$\Delta p_{fan,eff} = \Delta p_{fan} + [0.8-(-0.43)]\frac{0.075(23.2)^2}{2(32.2)}$$

$$= \Delta p_{fan} + 0.77\ lb_f/ft^2$$

This wind-assisted hourly averaged pressure is exceeded only ⅟₂ of the time (88 hours per year). When wind direction reverses, ıe outlet will be on the upwind wall and the inlet on the downwind all, producing wind-opposed flow, changing the sign from +0.15 ı -0.15 in. of water. The importance of these pressures depends n their size relative to the fan pressure rise Δp_{fan}, as shown in Figre 13.

.finimizing Wind Effect on System Volume

Wind effect can be reduced by careful selection of inlet and xhaust locations. Because wall surfaces are subject to a wide variy of positive and negative pressures, wall openings should be voided when possible. When they are required, wall openings ould be away from corners formed by building wings (see Figure 1). Mechanical ventilation systems should operate at a pressure igh enough to minimize wind effect. Low-pressure systems and opeller exhaust fans should not be used with wall openings unless ale ventilation rates are small or they are used in noncritical serices (e.g., storage areas).

Although roof air intakes in flow recirculation zones best inimize wind effect on system flow rates, current and future air uality in these zones must be considered. These locations ould be avoided if a contamination source exists or may be lded in the future. The best area is near the middle of the roof, ecause the negative pressure there is small and least affected by ıanges in wind direction (see Figure 8). Avoid edges of the roof ıd walls, where large pressure fluctuations occur. Either vertiıl or horizontal (mushroom) openings can be used. On roofs ith large areas, where intake may be outside the roof recirculaın zone, mushroom, or 180° gooseneck designs minimize ıpact pressure from wind flow. Vertical louvered openings or 1° goosenecks are undesirable for this purpose or for rain protection.

Heated air or contaminants should be exhausted vertically rough stacks, above the roof recirculation zone. Horizontal, louted (45° down), and 135° gooseneck discharges are undesirable, en for heat removal systems, because of their sensitivity to wind fects. A 180° gooseneck for hot-air systems may be undesirable cause of air impingement on tar and felt roofs. Vertically discharging stacks in a recirculation region (except near a wall) have ı advantage of being subjected only to negative pressure created wind flow over the tip of the stack. See Chapter 44 of the 2003 SHRAE Handbook—HVAC Applications for information on stack sign.

.hemical Hood Operation

Wind effects can interfere with safe chemical hood operaın. Supply volume variations can cause both disturbances at od faces and a lack of adequate hood makeup air. Volume ırges, caused by fluctuating wind pressures acting on the haust system, can cause momentary inadequate hood exhaust. highly toxic contaminants are involved, surging is unacceptle. The system should be designed to eliminate this condition. low-pressure exhaust systems, it is impossible to test the ods under wind-induced, surging conditions. These systems ould be tested during calm conditions for safe flow into the od faces, and rechecked by smoke tests during high wind ıditions. For more information on chemical hoods, see Chap- 14 of the 2003 *ASHRAE Handbook—HVAC Applications*. more information on stack and intake design, see Chapter of that volume.

BUILDING PRESSURE BALANCE AND INTERNAL FLOW CONTROL

Proper building pressure balance avoids flow conditions that make doors hard to open and cause drafts. In some cases (e.g., office buildings), pressure balance may be used to prevent confinement of contaminants to specific areas. In other cases (e.g., laboratories), the correct internal airflow is towards the contaminated area.

Pressure Balance

Although supply and exhaust systems in an internal area may be in nominal balance, wind can upset this balance, not only because of its effects on fan capacity but also by superimposing infiltrated or exfiltrated air (or both) on the area. These effects can make it impossible to control environmental conditions. Where building balance and minimum infiltration are important, consider the following:

- Design HVAC system with pressure adequate to minimize wind effects.
- Include controls to regulate flow rate, pressure, or both.
- Separate supply and exhaust systems to serve each building area requiring control or balance.
- Use revolving or other self-closing doors or double-door air locks to uncontrolled adjacent areas, particularly outside doors.
- Seal windows and other leakage sources.
- Close natural ventilation openings.

Internal Flow Control

Airflow direction is maintained by controlling pressure differentials between spaces. In a laboratory building, for example, peripheral rooms such as offices and conference rooms are kept at positive pressure, and laboratories at negative pressure, both with reference to corridor pressure. Pressure differentials between spaces are normally obtained by balancing supply system airflows in the spaces in conjunction with exhaust systems in the laboratories. Differential pressure instrumentation is normally used to control the airflow.

The pressure differential for a room adjacent to a corridor can be controlled using the corridor pressure as the reference. Outdoor pressure cannot usually control pressure differentials within internal spaces, even during periods of relatively constant wind velocity (wind-induced pressure). A single pressure sensor can measure the outside pressure at one point only and may not be representative of pressures elsewhere.

Airflow (or pressure) in corridors is sometimes controlled by an outdoor reference probe that senses static pressure at doorways and air intakes. The differential pressure measured between the corridor and the outside may then signal a controller to increase or decrease airflow to (or pressure in) the corridor. Unfortunately, it is difficult to locate an external probe where it will sense the proper external static pressure. High wind velocity and resulting pressure changes around entrances can cause great variations in pressure.

To measure ambient static pressure, the probe should be located where airflow streamlines are not affected by the building or nearby buildings. One possibility is at a height of $1.5R$, as shown in Figure 1. However, this is usually not feasible. If an internal space is to be pressurized relative to ambient conditions, the pressure must be known on each exterior surface in contact with the space. For example, a room at the northeast corner of the building should be pressurized with respect to pressure on both the north and east building faces, and possibly the roof. In some cases, multiple probes on a single building face may be required. Figures 4 to 8 may be used as guides in locating external pressure probes. System volume and pressure control is described in Chapter 46 of the 2003 *ASHRAE Handbook—HVAC Applications*.

NO FLOOR TO FLOOR COMPARISON

79

Variable air volume with reheat permits airflow to be reduced as the first step in control; heat is then initiated as the second step. Compared to constant-volume reheat, this procedure reduces operating cost appreciably because the amount of primary air to be cooled and secondary air to be heated is reduced. Many types of controls can provide control sequences with more than one minimum airflow. This type of control allows the box to go to a lower flow rate that just meets ventilation requirements at the lightest cooling loads, then increase to a higher flow rate when the heating coil is energized, further reducing reheat energy use. A feature can be provided to isolate the availability of reheat during the summer, except in situations where even low airflow would overcool the space and should be avoided or where increased humidity causes discomfort (e.g., in conference rooms when the lights are turned off).

Because the reheat coil requires some minimum airflow to deliver heat to the space, and because the reheat coil must absorb all of the cooling capacity of that minimum airflow before it starts to deliver heat to the space, energy use can be significantly higher than with throttling boxes that go fully closed.

Induction. The VAV induction system uses a terminal unit to reduce cooling capacity by simultaneously reducing primary air and inducing room or ceiling air (replacing the reheat coil) to maintain a relatively constant room supply volume. This operation is the reverse of the bypass box. The primary-air quantity decreases with load, retaining the savings of VAV, and the air supplied to the space is kept relatively constant to avoid the effect of stagnant air or low air movement. VAV induction units require a higher inlet static pressure, which requires more fan energy, to achieve the velocities necessary for induction.

Fan-Powered. Fan-powered systems are available in either parallel or series airflow. In **parallel-flow** units, the fan is located outside the primary airstream to allow intermittent fan operation. A backdraft damper on the terminal fan prevents conditioned air from escaping into the return air plenum when the terminal fan is off. In series units, the fan is located in the primary airstream and runs continuously when the zone is occupied. These constant-airflow fan boxes in a common return plenum can help maintain indoor air quality by recirculating unvitiated air from overventilated zones to zones with greater outside air ventilation requirements.

Fan-powered systems, both series and parallel, are often selected because they maintain higher air circulation through a room at low loads but still retain the advantages of VAV systems. As the cold primary-air valve modulates from maximum to minimum (or closed), the unit recirculates more plenum air. In a perimeter zone, a hot-water heating coil, electric heater, baseboard heater, or remote radiant heater can be sequenced with the primary-air valve to offset external heat losses. Between heating and cooling operations, the fan only recirculates ceiling air. This permits heat from lights to be used for space heating for maximum energy saving. During unoccupied periods, the main supply air-handling unit remains off and individual fan-powered heating zone terminals are cycled to maintain required space temperature, thereby reducing operating cost during unoccupied hours.

Fans for fan-powered air-handling units operated in series are sized and operated to maintain minimum static pressures at the unit inlet connections. This reduces the fan energy for the central air handler, but the small fans in fan-powered units are less efficient than the large air handler fans. As a result, the series fan-powered unit (where small fans operate continuously) may use more fan energy than a throttling unit system. However, the extra fan energy may be more than offset by the reduction in reheat through the recovery of plenum heat and the ability to operate a small fan to deliver heat during unoccupied hours where heat is needed.

Because fan-powered boxes involve an operating fan, they may generate higher sound levels than throttling boxes. Acoustical ceilings generally are not very effective sound barriers, so extra care should be taken in considering the sound level in critical spaces near fan-powered terminal units.

Both parallel and series fan-powered terminal units may be provided with filters. The constant (series) fan VAV terminal can accommodate minimum (down to zero) flow at the primary-air inlet while maintaining constant airflow to the space.

Both types of fan-powered units and induction terminal units are usually located in the ceiling plenum to recover heat from lights. This allows these terminals to be used without reheat coils in internal spaces. Perimeter zone units are sometimes located above the ceiling of an interior zone where heat from the lights maintains a higher plenum temperature. Provisions must still be made for morning warm-up and night heating. Also, interior spaces with a roof load must have heat supplied either separately in the ceiling or at the terminal.

Terminal Humidifiers

Most projects requiring humidification use steam. This can be centrally generated as part of the heating plant, where potential contamination from water treatment of the steam is more easily handled and therefore of less concern. Where there is a concern, local generators (e.g., electric or gas) that use treated water are used. Compressed-air and water humidifiers are used to some extent, and supersaturated systems are used exclusively for special circumstances, such as industrial processes. Spray-type washers and wetted coils are also more common in industrial facilities. When using water directly, particularly in recirculating systems, the water must be treated to avoid dust accumulation during evaporation and the build-up of bacterial contamination.

Terminal Filters

In addition to air-handling unit filters, terminal filters may used at the supply outlets to protect particular conditioned spaces where an extra-clean environment is desired. Chapter 24 discusses this topic in detail.

AIR DISTRIBUTION SYSTEM CONTROLS

Controls should be automatic and simple for best operating and maintenance efficiency. Operations should follow a natural sequence. Depending on the space need, one controlling thermostat closes a normally open heating valve, opens the outside air mixing dampers, or opens the cooling valve. In certain applications, an enthalpy controller, which compares the heat content of outside air to that of return air, may override the temperature controller. This control opens the outside air damper when conditions reduce the refrigeration load. On smaller systems, a dry-bulb control saves the cost of the enthalpy control and approaches these savings when an optimum changeover temperature, above the design dew point, is established. Controls are discussed in more detail in Chapter 46 of the 2003 *ASHRAE Handbook—HVAC Applications*.

NO FLOOR TO FLOOR CORRIDOR

Air-handling systems, especially variable air volume systems, should include means to measure and control the amount of outside air being brought in to ensure adequate ventilation for acceptable indoor air quality. Strategies include the following:

- Separate constant-volume 100% outside air ventilation systems
- Outside air injection fan
- Directly measuring the outside air flow rate
- Modulating the return damper to maintain a constant pressure drop across a fixed outside air orifice
- Airflow-measuring systems that measure both supply and return air volumes and maintain a constant difference between them.
- CO_2- and/or VOC-based demand-controlled ventilation

A minimum outside air damper with separate motor, selected for a velocity of 1500 fpm, is preferred to one large outside air damper with minimum stops. A separate damper simplifies air balancing. Proper selection of outside, relief, and return air dampers is critical

80

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for efficient operation. Most dampers are grossly oversized and are, in effect, unable to control. One way to solve this problem is to provide maximum and minimum dampers. A high velocity across a wide-open damper is essential to its providing effective control.

A mixed-air temperature control can reduce operating costs and also reduce temperature swings from load variations in the conditioned space. Chapter 46 of the 2003 *ASHRAE Handbook—HVAC Applications* shows control diagrams for various arrangements of central system equipment. Direct digital control (DDC) is common, and most manufacturers offer either a standard or optional DDC package for equipment, including air-handling units, terminal units, etc. These controls offer considerable flexibility. DDC controls offer the additional advantage of the ability to record actual energy consumption or other operating parameters of various components of the system, which can be useful for optimizing control strategies.

Constant-Volume Reheat. This system typically uses two subsystems for control: one controls the discharge air conditions from the air-handling unit, and the other maintains the space conditions by controlling the reheat coil.

Variable Air Volume. Air volume can be controlled by duct-mounted terminal units serving multiple air outlets in a control zone or by units integral to each supply air outlet.

Pressure-independent volume-regulator units control flow in response to the thermostat's call for heating or cooling. The required flow is maintained regardless of fluctuation of the VAV unit inlet or system pressure. These units can be field- or factory-adjusted for maximum and minimum (or shutoff) air settings. They operate at inlet static pressures as low as 0.2 in. of water.

Pressure-dependent devices control air volume in response to a unit thermostatic (or relative humidity) device, but flow varies with the inlet pressure variation. Generally, airflow oscillates when pressure varies. These units do not regulate flow but position the volume-regulating device in response to the thermostat. They are the least expensive units but should only be used where there is no need for maximum or minimum limit control and when the pressure is stable.

The type of controls available for VAV units varies with the terminal device. Most use either pneumatic or electric controls and may be either self-powered or system-air-actuated. Self-powered controls position the regulator by using liquid- or wax-filled power elements. System-powered devices use air from the air supplied to the space to power the operator. Components for both control and regulation are usually contained in the terminal device.

To conserve power and limit noise, especially in larger systems, fan operating characteristics and system static pressure should be controlled. Many methods are available, including fan speed control, variable-inlet vane control, fan bypass, fan discharge damper, and variable-pitch fan control. The location of pressure-sensing devices depends, to some extent, on the type of VAV terminal unit used. Where pressure-dependent units without controllers are used, the system pressure sensor should be near the static pressure midpoint of the duct run to ensure minimum pressure variation in the system. Where pressure-independent units are installed, pressure controllers may be at the end of the duct run with the highest static pressure loss. This sensing point ensures maximum fan power savings while maintaining the minimum required pressure at the last terminal.

As flow through the various parts of a large system varies, so does static pressure. Some field adjustment is usually required to find the best location for the pressure sensor. In many systems, the initial location is two-thirds to three-fourths of the distance from the supply fan to the end of the main trunk duct. As the pressure at the system control point increases as terminal units close, the pressure controller signals the fan controller to position the fan volume control, which reduces flow and maintains constant pressure. Many systems measure flow rather than pressure and, with the development of economical DDC, each terminal unit (if necessary) can be monitored and the supply and return air fans modulated to exactly match the demand.

Dual-Duct. Because dual-duct systems are generally more costly to install than single-duct systems, their use is less widespread. DDC, with its ability to maintain set points and flow accurately, can make dual-duct systems worthwhile for certain applications. They should be seriously considered as alternatives to single-duct systems.

Personnel. The skill levels of personnel operating and maintaining the air conditioning and controls should be considered. In large research and development or industrial complexes, experienced personnel are available for maintenance. On small and sometimes even large commercial installations, however, office managers are often responsible, so designs must be in accordance with their capabilities.

Water System Interface. On large hydronic installations where direct blending is used to maintain (or reset) the secondary-water temperature, the system valves and coils must be accurately sized for proper control. Many designers use variable flow for hydronic as well as air systems, so the design must be compatible with the air system to avoid operating problems.

Relief Fans. In many applications, relief or exhaust fans can be started in response to a signal from the economizer control or to a space pressure controller. The main supply fan must be able to handle the return air pressure drop when the relief fan is not running.

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81

2003 ASHRAE APPLICATIONS HANDBOOK (S)

CHAPTER 46

DESIGN AND APPLICATION OF CONTROLS

AUTOMATIC control of HVAC systems and equipment usually includes control of temperature, humidity, pressure, and flow e. Automatic control sequences equipment operation to meet load uirements and provides safe operation of the equipment, using umatic, mechanical, electrical, electronic, and direct digital con- l devices.

This chapter covers (1) control of HVAC elements, (2) control of ical systems, (3) limit control for safe operation, and (4) design of trols for specific HVAC applications. Chapter 15 of the 2001 *IRAE Handbook—Fundamentals* covers the basics of control, es of control components, and commissioning of control systems.

CONTROL OF HVAC ELEMENTS

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Load affects the rate of heat input to a hydronic system. Rate con- is accomplished by cycling and modulating the flame and by ing boilers on and off. Flame cycling and modulation are han- l by the boiler control package. The control designer decides er what circumstances to add or drop a boiler and at what tem- ture to control the boiler supply water.

Hot-water distribution control includes temperature control at hot-water boilers or converter, reset of heating water tempera- and control for multiple zones. Other factors that need to be idered include (1) minimum water flow through the boilers, protection of boilers from temperature shock, and (3) coil e protection. If multiple or alternative heating sources (such ondenser heat recovery or solar storage) are used, the control rgy must also include a means of sequencing hot-water es or selecting the most economical source.

gure 1 shows a system for load control of a gas or oil-fired r. Boiler safety controls usually include flame-failure, high- erature, and other cutouts. Intermittent burner firing usually ols capacity, although fuel input modulation is common in r systems. In most cases, the boiler is controlled to maintain a ant water temperature, although an outside air thermostat can the temperature if the boiler is not used for domestic water ig. Figure 1 contains a typical reset schedule. To minimize ensation of flue gases and boiler damage, water temperature d not be reset below that recommended by the manufacturer, lly 140°F. Larger systems with sufficiently high pump oper- costs can use variable-speed pump drives, pump discharge i with minimum-flow bypass valves, or two-speed drives to : secondary pumping capacity to match the load.

t-water heat exchangers or steam-to-water converters are imes used instead of boilers as hot-water generators. Convert- ically do not include a control package; therefore, the engi- ust design the control scheme. The schematic in Figure 2 can l with either low-pressure steam or boiler water ranging from 260°F. The supply water thermostat controls a modulating

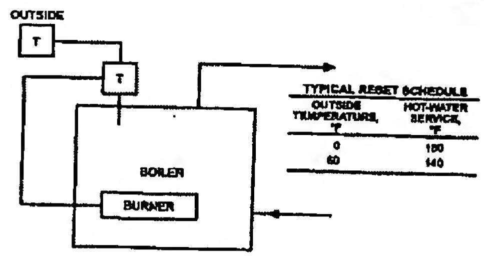

Fig. 1 Boiler Control

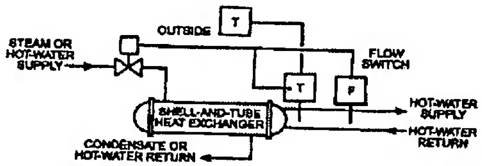

Fig. 2 Steam-to-Water Heat Exchanger Control

two-way valve in the steam (or hot-water) supply line. An outside thermostat usually resets the supply water temperature downward as the load decreases to improve the controllability of heating valves at low load and to reduce piping losses. A flow switch interlock should close the two-way valve when the hot-water pump is not operating. With integrated computer-based control, feedback from zone heating valves can be used to control the starting and stopping of the hot-water pumps. On constant-flow systems, the feedback can be used to reset the hot-water temperature to the lowest temperature that meets zone requirements.

Fan

The most efficient way to change the output of a fan is to change its speed. Because of their simplicity and high efficiency, variable-frequency drives are widely used. Though less efficient, eddy current drives are also an option for electronically controlling fan speed. Other ways of controlling fan ouput include using inlet cones, inlet guide vanes, and discharge or scroll dampers. Axial fans can be controlled by varying the pitch of the blade. Also, dampers and ducting can simply bypass some of the air from the supply side of the fan to the return side (Figure 3). Bypassing does not change the output of the fan, but it can allow the fan to accommodate flow variations in the distribution system without fan instability. The final selection of a control device is determined by efficiency requirements and available funding.

The paration of this chapter is assigned to TC 1.4, Control Theory and Ap tion.

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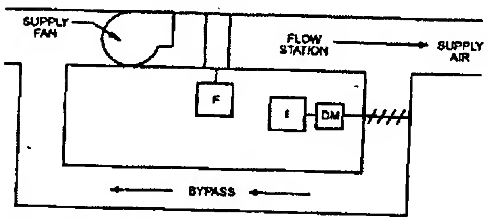

Fig. 3 Fan Bypass Control to Prevent Supply Fan Instability

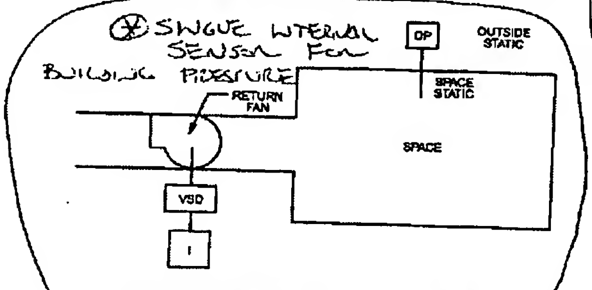

Fig. 4 Direct Building Pressurization Control

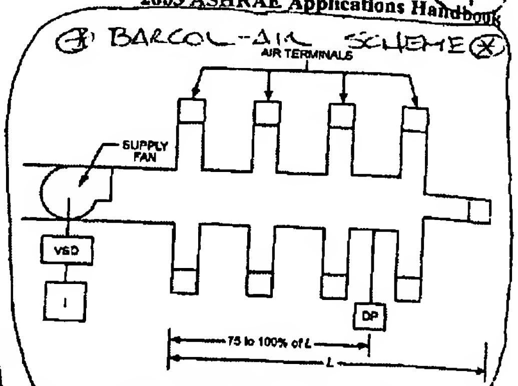

Fig. 5 Duct Static-Pressure Control

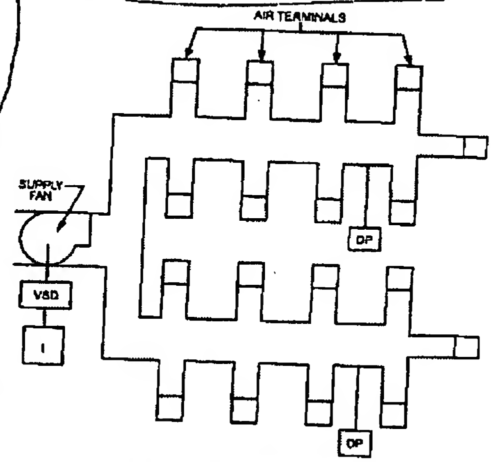

Fig. 6 Multiple Static Sensors

Static-pressure control is required in systems having variable flow rates. To conserve fan energy, the static-pressure controller should be set at the lowest control point permitting proper air distribution at design conditions. The controller requires proportional-plus-integral (PI) control because it eliminates offset while maintaining stability. In proportional-only control, the low proportional gain required to stabilize fan control loops allows static pressure to offset upward as the load decreases, which causes the supply fan to consume more energy.

Differential static-pressure control is used to pressurize a building or space relative to adjacent spaces or the outside. Typical applications include clean rooms (positive pressure to prevent infiltration), laboratories (positive or negative, depending on use), and various manufacturing processes, such as spray-painting rooms. The pressure controller usually modulates dampers in the supply duct to maintain the desired pressure as exhaust volumes change. A method for control of the return fan requires measuring the space and outside static pressures (Figure 4). The location for measuring inside static pressure must be selected carefully: away from doors and openings to the outside, away from elevator lobbies, and, when using a sensor, in a large representative area shielded from drafts. The outside location must likewise be selected carefully, typically 10 to 15 ft above the building and oriented to minimize wind effects from all directions. The amount of minimum outside air varies with building permeability and exhaust fan operation. Control of building pressurization can affect the amount of outside air entering the building.

Duct static-pressure control for variable air volume (VAV) and other terminal systems maintains a static pressure at a measurement point. The most common application for static-pressure control is fan output control in VAV systems. The pressure sensor must be properly placed to maintain optimum pressure throughout the supply duct. Experience indicates that performance is satisfactory when the sensor is located at 75 to 100% of the distance from the first to the most remote terminal. If the sensor is located at less than 100% of the distance, the control set point should be adjusted higher to account for the pressure loss between the sensor and the remote terminal (Figure 5). Care must be taken in selecting the reference sensor location. Controller upset from opening and closing doors, elevator shafts, and other sources of air turbulence should also be prevented. The pressure selected provides a minimum static pressure to all air terminal units during all supply fan design conditions.

Multiple static sensors (Figure 6) are required when more than one branch duct runs from the supply fan. The sensor with the highest static requirement controls the fan. Because duct run-outs may vary, a control that uses individual set points for each measurement is preferred.

VAV systems typically incorporate a duct static-pressure control loop to control the supply fan speed output. In a single-duct VAV system, the duct static pressure set point is usually selected by the designer. The sensor should be located in the ductwork where the established set point ensures proper operation of the zone VAV boxes under varying load (supply airflow) conditions. A shortcoming of this approach is that static-pressure control is based on the

83

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readings of a single sensor that is assumed to represent the pressure available to all VAV boxes. If the sensor malfunctions or is placed in a location that is not representative, operating problems will result.

An alternative approach to supply fan control in a VAV system uses flow readings from the direct digital control (DDC) zone terminal boxes to integrate zone VAV requirements with supply fan operation. Englander and Norford (1992) suggest that duct static pressure and fan energy can be reduced without sacrificing occupant comfort or adequate ventilation. They compared modified PI and heuristic control algorithms using simulation and demonstrated that either static pressure or fan speed can be regulated directly using a flow error signal from one or more zones. They noted that component modeling limitations constrained their results primarily to a comparison of the control algorithms. The results show that both PI and heuristic control schemes work, but the authors suggest that a hybrid of the two might be ideal.

Supply fan warm-up control for systems having a return fan must prevent the supply fan from delivering more airflow than the return fan maximum capacity during warm-up mode (Figure 7).

Return fan static control from returns having local (zoned) flow control is identical to supply fan static control (Figure 5). Return fan control for VAV systems is required for proper building pressurization and minimum outside air. The return fan is controlled to maintain exhaust and return air plenum pressure. The exhaust air damper is controlled to maintain building static pressure (Figure 8). This ensures that the supply fan does not pull in outside air backward through the exhaust air dampers (Seem et al. 2000).

Airflow tracking uses duct airflow measurements to control the return air fans (Figure 9). Typical sensors, called flow stations, are multiple-point, pitot tube, and averaging. Provisions must be made for exhaust fan switching to maintain pressurization of the building. Warm-up is accomplished by setting the return airflow equal to the supply fan airflow, usually with exhaust fans turned off and limiting supply fan volume to return fan capability. During night cooldown, the return fan operates in the normal mode.

VAV systems that use return or relief fans require control of airflow through the return or relief air duct systems. Return fans are commonly used in VAV systems to help ensure adequate air distribution and acceptable zone pressurization. In a return fan VAV system, there is significant potential for control system instability because of the interaction of control variables (Avery 1992). In a typical system, these variables might include supply fan speed, supply duct static pressure, return fan speed, mixed air temperature, outside and return air damper flow characteristics, and wind pressure effect on the relief louver. The interaction of these variables and the selection of control schemes to minimize or eliminate interaction must be considered carefully. Mixed air damper sizing and selection are particularly important. Zone pressurization, building construction, and outside wind velocity must be considered. The resultant design helps ensure proper air distribution, especially through the return air duct. Kettler (1995) suggests that small errors in sensing total airflow and return flow can cause significant errors in control of the differential flow, making this approach unsatisfactory for minimum outside ventilation control.

Sequencing fans for VAV systems reduces airflow more than other methods and results in greater operating economy and more stable fan operation if airflow reductions are significant. Alternating fans usually provides greater reliability. Centrifugal fans are controlled to keep system disturbances to a minimum when additional fans are started. The added fan is started and slowly brought to capacity while the capacity of the operating fans is simultaneously reduced. The combined output of all fans then equals the output before fan addition.

Vaneaxial fans usually cannot be sequenced in the same manner as centrifugal fans. To avoid stall, the operating fans must be reduced to some minimum level of airflow. Then, additional fans may be started and all fans modulated in parallel to achieve equilibrium.

Unstable fan operation in VAV systems can usually be avoided by proper fan sizing. However, if airflow reduction is large (typically over 60%), fan sequencing is usually required to maintain airflow in the fan's stable range.

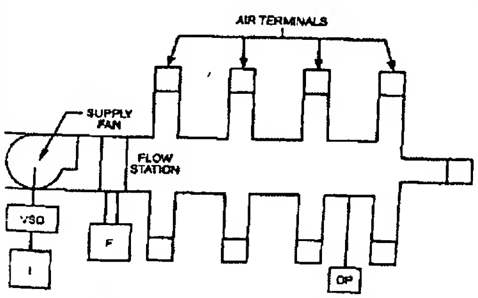
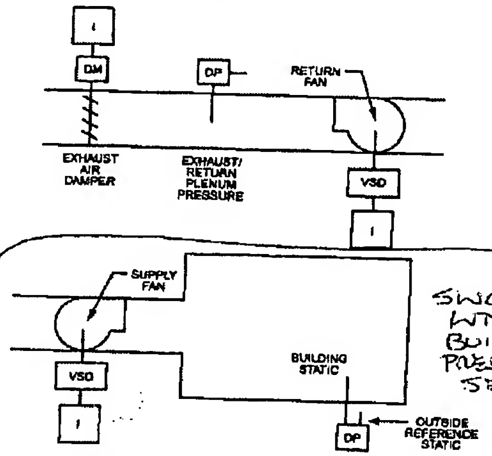


Fig. 7 Supply Fan Warm-Up Control



SINGLE INTERNAL BUILDING PRESSURE SENSOR

Fig. 8 Duct Static Control of Return Fan

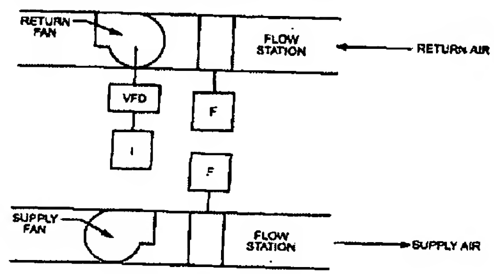


Fig. 9 Airflow Tracking Control

84

Humidification can be achieved by adding moisture to supply air. Evaporative pans (usually heated), steam jets, and atomizing spray tubes are all used for space humidification. A space or return air humidity sensor provides the necessary signal for the controller. A humidity sensor in the duct should be used to minimize moisture carryover or condensation in the duct (Figure 28). With proper use and control, humidifiers can achieve high space humidity, although they more often maintain design minimum humidity during the heating season.

Outside Air Control

Fixed minimum outside air control provides ventilation air, space pressurization (exfiltration), and makeup air for exhaust fans. For systems without return fans, the outside air damper is interlocked to remain open only when the supply fan operates (Figure 29). The minimum outside air damper should open quickly when the fan turns on, to prevent excessive negative duct pressurization. In some applications, the fan on-off switch opens the outside air damper before the fan is started. The rate of outside airflow is determined by the damper opening and by the pressure difference between the mixed air plenum and the outside air plenums.

For systems with return fans, two variations of fixed minimum outside air control are used. Minimum outside airflow is determined by the pressure drop across the outside damper at minimum position, and an injection fan (Figure 30) or airflow station is installed in the minimum outside air section (Figure 31). If the outside air supplied is greater than the difference between the supply and return fan airflows, a variation of economizer cycle control is used (Figure 31).

In systems using 100% outside air, all air goes to the fan and no air is returned (Figure 32). The outside air damper is interlocked and usually opens before the fan starts.

Radiant Cooling and Heating

Radiation can be used either alone or to supplement another heater. The control strategy depends on the function performed. For a radiation-only heating application, rooms are usually controlled individually; each radiator and convector is equipped with an automatic control valve. Depending on room size, one thermostat may control one valve or several valves in unison. The thermostat can be placed in the return air to the unit or on a wall at occupant level. Return air control is generally less accurate and results in wider space-temperature fluctuations. When the space is controlled for the comfort of seated occupants, wall-mounted thermostats give the best results.

For supplemental heating applications, where perimeter radiation is used only to offset perimeter heat losses (the zone or space load is handled separately by a zone air system), outside reset of the water temperature to the radiation should be considered. Radiation can be zoned by exposure, and the compensating outside sensor can be located to sense compensated inside (outside) temperature, solar load, or both.

Radiant panels combine controlled-temperature room surfaces with central air conditioning and ventilation. The radiant panel can be in the floor, walls, or ceiling. Panel temperature is maintained by circulating water or air or by electric resistance. The central air system can be a basic one-zone, constant-temperature, constant-volume system, with the radiant panel operated by individual room control thermostats, or it can include some or all the features of

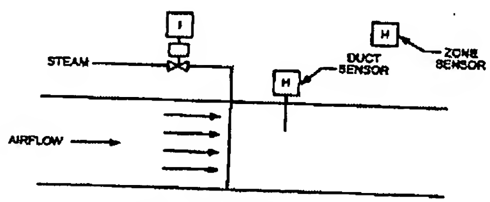


Fig. 28 Steam Jet Humidifier

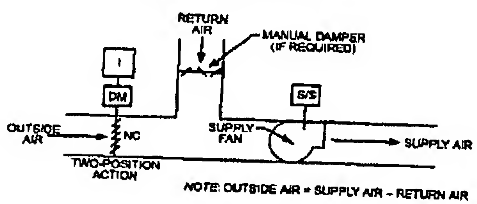


Fig. 29 Fixed Minimum Outside Air Control Without Return Fans

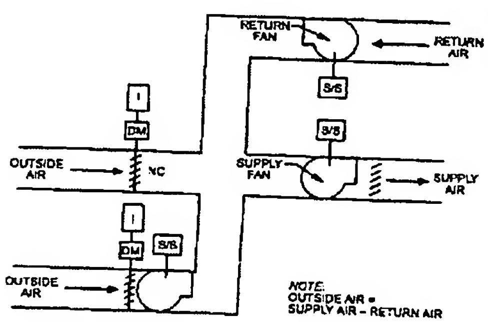


Fig. 30 Fixed Minimum Outside Air Control With Return Fans

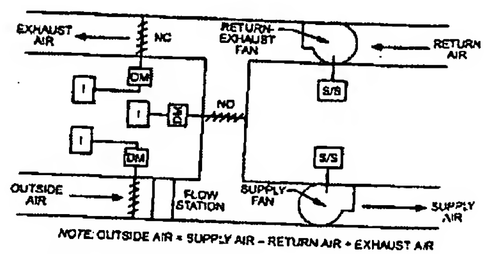


Fig. 31 Fixed Minimum Outside Air Control With Return-Exhaust Fans

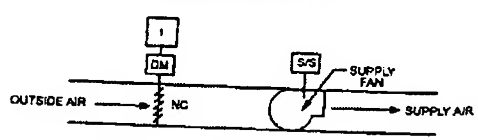


Fig. 32 100% Outside Air Control

2005 ASHRAE HANDBOOK- FUNAMENTALS

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tem provides an air change effectiveness of about 1. Therefore, Table 6.1 values of ASHRAE *Standard* 62.1 are appropriate for ign of commercial and institutional buildings when the ventila- 1 rate procedure is used. If the indoor air quality procedure of *ndard* 62.1 is used, then actual pollutant sources and the air nge effectiveness must be known for the successful design of AC systems that have fixed ventilation airflow rates.

ASHRAE *Standard* 129 describes a method for measuring air nge effectiveness of mechanically vented spaces and buildings h limited air infiltration, exfiltration, and air leakage with sur- nding indoor spaces.

DRIVING MECHANISMS FOR VENTILATION AND INFILTRATION

Natural ventilation and infiltration are driven by pressure differ- es across the building envelope caused by wind and air density erences due to temperature differences between indoor and out- r air (buoyancy, or the stack effect). Mechanical air-moving sys- s also induce pressure differences across the envelope due to the ration of appliances, such as combustion devices, leaky forced- thermal distribution systems, and mechanical ventilation sys- s. The indoor/outdoor pressure difference at a location depends he magnitude of these driving mechanisms as well as on the acteristics of the openings in the building envelope (i.e., their tions and the relationship between pressure difference and air- for each opening).

:k Pressure

tack pressure is the hydrostatic pressure caused by the weight of umn of air located inside or outside a building. It can also occur in a flow element, such as a duct or chimney, that has vertical ration between its inlet and outlet. The hydrostatic pressure in ir depends on density and the height of interest above a refer- point.

ir density is a function of local barometric pressure, tempera- and humidity ratio, as described by Chapter 6. As a result, lard conditions should not be used to calculate the density. For ple, a building site at 5000 ft has an air density that is about less than if the building were at sea level. An air temperature ase from −20 to 70°F causes a similar air density difference. bined, these elevation and temperature effects reduce the air ty about 45%. Moisture effects on density are generally neg- e, so the dry air density can be used instead, except in hot, d climates when the air is hot and close to saturation. For ple, saturated air at 105°F has a density about 5% less than that air.

suming temperature and barometric pressure are constant over ight of interest, the stack pressure decreases linearly as the tion above the reference point increases. For a single column the stack pressure can be calculated as

$$p_s = p_r - C_1 \rho g H \qquad (16)$$

= stack pressure, in. of water
= stack pressure at reference height, in. of water
= gravitational acceleration, 32.2 ft/s²
= indoor or outdoor air density, lb_m/ft^3
= height above reference plane, ft
= unit conversion factor = 0.00598 (in. of water)·ft·s^2/lb_m

tall buildings or when significant temperature stratification indoors, Equation (16) should be modified to include the gradient over the height of the building.

perature differences between indoors and outdoors cause ressure differences that drive airflows across the building e. Sherman (1991) showed that any single-zone building can be treated as an equivalent box from the point of view of stack effect, if its leaks follow the power law. The building is then characterized by an effective stack height and neutral pressure level (NPL) or leak- age distribution (see the section on Neutral Pressure Level). Once calculated, these parameters can be used in physical, single-zone models to estimate infiltration.

Neglecting vertical density gradients, the stack pressure differ- ence for a horizontal leak at any vertical location is given by

$$\Delta p_s = C_1(\rho_o - \rho_i)g(H_{NPL} - H)$$

$$= C_1\rho_o\left(\frac{T_o - T_i}{T_i}\right)g(H_{NPL} - H) \qquad (17)$$

where

T_o = outdoor temperature, °R
T_i = indoor temperature, °R
ρ_o = outdoor air density, lb/ft^3
ρ_i = indoor air density, lb/ft^3
H_{NPL} = height of neutral pressure level above reference plane without any other driving forces, ft

Chastain and Colliver (1989) showed that when there is stratifi- cation, the average of the vertical distribution of temperature differ- ences is more appropriate to use in Equation (17) than the localized temperature difference near the opening of interest.

By convention, stack pressure differences are positive when the building is pressurized relative to outdoors, which causes flow out of the building. Therefore, in the absence of other driving forces and assuming no stack effect is within the flow elements themselves, when the indoor air is warmer than outdoors, the base of the build- ing is depressurized and the top is pressurized relative to outdoors; when the indoor air is cooler than outdoors, the reverse is true.

In the absence of other driving forces, the location of the NPL is influenced by leakage distribution over the building exterior and by interior compartmentation. As a result, the NPL is not necessarily located at the mid-height of the building, nor is it necessarily unique. NPL location and leakage distribution are described later in the section on Combining Driving Forces.

For a penetration through the building envelope for which (1) there is a vertical separation between its inlet and outlet and (2) the air inside the flow element is not at the indoor or outdoor temperature, such as in a chimney, more complex analyses than Equation (17) are required to determine the stack effect at any location on the building envelope.

Wind Pressure

When wind impinges on a building, it creates a distribution of static pressures on the building's exterior surface that depends on the wind direction, wind speed, air density, surface orientation, and surrounding conditions. Wind pressures are generally positive with respect to the static pressure in the undisturbed airstream on the windward side of a building and negative on the leeward sides. However, pressures on these sides can be negative or positive, depending on wind angle and building shape. Static pressures over building surfaces are almost proportional to the velocity head of the undisturbed airstream. The wind pressure or velocity head is given by the Bernoulli equation, assuming no height change or pressure losses:

$$p_w = C_2 C_p \rho \frac{U^2}{2} \qquad (18)$$

where

p_w = wind surface pressure relative to outdoor static pressure in undisturbed flow, in. of water
ρ = outside air density, lb_m/ft^3 (about 0.075)

86

U = wind speed, mph
C_p = wind surface pressure coefficient, dimensionless
$C_?$ = unit conversion factor = 0.0129 (in. of water)·ft³/lb$_m$·mph²

C_p is a function of location on the building envelope and wind direction. Chapter 16 provides additional information on the values of C_p.

Most pressure coefficient data are for winds normal to building surfaces. Unfortunately, for a real building, this fixed wind direction rarely occurs, and when the wind is not normal to the upwind wall, these pressure coefficients do not apply. A harmonic trigonometric function was developed by Walker and Wilson (1994) to interpolate between the surface average pressure coefficients on a wall that were measured with the wind normal to each of the four building surfaces. This function was developed for low-rise buildings three stories or less in height. For each wall of the building, C_p is given by

$$C_p(\phi) = \frac{1}{2}\{[C_p(1)+C_p(2)](\cos^2\phi)^{1/4} + [C_p(1)-C_p(2)](\cos\phi)^{3/4} + [C_p(3)+C_p(4)](\sin^2\phi)^2 + [C_p(3)-C_p(4)]\sin\phi\} \tag{19}$$

where

$C_p(1)$ = pressure coefficient when wind is at 0°
$C_p(2)$ = pressure coefficient when wind is at 180°
$C_p(3)$ = pressure coefficient when wind is at 90°
$C_p(4)$ = pressure coefficient when wind is at 270°
ϕ = wind angle measured clockwise from the normal to Wall 1

The measured data used to develop the harmonic function from Akins et al. (1979) and Wiren (1985) show that typical values for the pressure coefficients are $C_p(1) = 0.6$, $C_p(2) = -0.3$, $C_p(3) = C_p(4) = -0.65$. Because of the geometry effects on flow around a building, the application of this interpolation function is limited to low-rise buildings that are of rectangular plan form (i.e., not L-shaped) with the longest wall less than three times the length of the shortest wall. For less regular buildings, simple correlations are inadequate and building-specific pressure coefficients are required. Chapter 16 discusses wind pressures for complex building shapes and for high-rise buildings in more detail.

The wind speed most commonly available for infiltration calculations is the wind speed measured at the local weather station, typically the nearest airport. This wind speed needs to be corrected for reductions caused by the difference between the height where the wind speed is measured and the height of the building and reductions due to shelter effects.

The reference wind speed used to determine pressure coefficients is usually the wind speed at the eaves height for low-rise buildings and the building height for high-rise buildings. However, meteorological wind speed measurements are made at a different height (typically 33 ft) and at a different location. The difference in terrain between the measurement station and the building under study must also be accounted for. Chapter 16 shows how to calculate the effective wind speed U_H from the reference wind speed U_{met} using boundary layer theory and estimates of terrain effects.

In addition to the reduction in wind pressures due to the reduction in wind speed, the effects of local shelter also act to reduce wind pressures. The shielding effects of trees, shrubbery, and other buildings within several building heights of a particular building produce large-scale turbulence eddies that not only reduce effective wind speed but also alter wind direction. Thus, meteorological wind speed data must be reduced carefully when applied to low buildings.

Ventilation rates measured by Wilson and Walker (1991) for a row of houses showed reductions in ventilation rates of up to a factor of three when the wind changed direction from perpendicular to parallel to the row. They recommended estimating wind shelter for winds perpendicular to each side of the building and then using the interpolation function in Equation (20) to find the wind shelter for intermediate wind angles:

$$s = \frac{1}{2}\left\{\begin{matrix}[s(1)+s(2)]\cos^2\phi + [s(1)-s(2)]\cos\phi \\ + [s(3)+s(4)]\sin^2\phi + [s(3)-s(4)]\sin\phi\end{matrix}\right\} \tag{20}$$

where

s = shelter factor for the particular wind direction ϕ
$s(i)$ = shelter factor when wind is normal to Wall i (i = 1 to 4, for four sides of a building)

Although the above method gives a realistic variation of wind shelter effects with wind direction, estimates for the numerical values of wind shelter factor s for each of the four cardinal directions must be provided. Table 8 in the section on Residential Calculation Examples lists typical shelter factors. The wind speed used in Equation (18) is then given by

$$U = sU_H \tag{21}$$

The magnitude of the pressure differences found on the surfaces of buildings varies rapidly with time because of turbulent fluctuations in the wind (Etheridge and Nolan 1979; Grimsrud et al. 1979). However, the use of average wind pressures to calculate pressure differences is usually sufficient to calculate average infiltration values.

Mechanical Systems

The operation of mechanical equipment, such as supply or exhaust systems and vented combustion devices, affects pressure differences across the building envelope. The interior static pressure adjusts such that the sum of all airflows through the openings in the building envelope plus equipment-induced airflows balance to zero. To predict these changes in pressure differences and airflow rates caused by mechanical equipment, the location of each opening in the envelope and the relationship between pressure difference and airflow rate for each opening must be known. The interaction between mechanical ventilation system operation and envelope airtightness has been discussed for low-rise buildings (Nylund 1980) and for office buildings (Persily and Grot 1985a; Tamura and Wilson 1966, 1967b).

Air exhausted from a building by a whole-building exhaust system must be balanced by increasing the airflow into the building through other openings. As a result, the airflow at some locations changes from outflow to inflow. For supply fans, the situation is reversed and envelope inflows become outflows. Thus, the effects a mechanical system has on a building must be considered. Depressurization caused by an improperly designed exhaust system can increase the rate of radon entry into a building and interfere with the proper operation of combustion device venting or other exhaust systems. Depressurization can also force moist outdoor air through the building envelope; for example, during the cooling season in hot humid climates, moisture may condense within the building envelope. A similar phenomenon, but in reverse, can occur during the heating season in cold climates if the building is depressurized.

The interaction between mechanical systems and the building envelope also pertains to systems serving zones of buildings. The performance of zone-specific exhaust or pressurization systems is affected by the leakage in zone partitions as well as in exterior walls.

Mechanical systems can also create infiltration-driving forces in single-zone buildings. Specifically, some single-family houses with central forced-air duct systems have multiple supply registers, yet only a central return register. When internal doors are closed in these houses, large positive indoor-outdoor pressure differentials are created for rooms with only supply registers, whereas the room with the return duct tends to depressurize relative to outside. This is caused by the resistance of internal door undercuts to flow from the

2005 ASHRAE HANDBOOK – FUNDAMENTALS

Y

supply register to the return (Modera et al. 1991). The magnitudes of the indoor/outdoor pressure differentials created have been measured to average 0.012 to 0.024 in. of water (Modera et al. 1991).

Building envelope airtightness and interzonal airflow resistance can also affect the performance of mechanical systems. The actual airflow rate delivered by these systems, particularly ventilation systems, depends on the pressure they work against. This effect is the same as the interaction of a fan with its associated ductwork, which is discussed in Chapter 35 of this volume and Chapter 18 of the 2004 *ASHRAE Handbook—HVAC Systems and Equipment*. The building envelope and its leakage must be considered part of the ductwork in determining the pressure drop of the system.

Duct leakage can cause similar problems. Supply leaks to the outside will tend to depressurize the building; return leaks to the outside will tend to pressurize it.

Combining Driving Forces

The pressure differences due to wind pressure, stack pressure, and mechanical systems are considered in combination by adding them together and then determining the airflow rate through each opening due to this total pressure difference. The air flows must be determined in this manner, as opposed to adding the airflow rates due to the separate driving forces, because the airflow rate through each opening is not linearly related to pressure difference.

For uniform indoor air temperatures, the total pressure difference across each leak can be written in terms of a reference wind parameter P_U and stack effect parameter P_T common to all leaks:

$$P_U = \rho_o \frac{U_H^2}{2} \qquad (22)$$

$$P_T = g\rho_o\left(\frac{T_o - T_i}{T_i}\right) \qquad (23)$$

where T = air temperature, °R.

The pressure difference across each leak (with positive pressures for flow into the building) is then given by

$$\Delta p = C_2 s^2 C_p P_U + H P_T + \Delta p_I \qquad (24)$$

where Δp_I = pressure that acts to balance inflows and outflows including mechanical system flows). Equation (24) can then be applied to every leak for the building with the appropriate values of C_p, s, and H. Thus, each leak is defined by its pressure coefficient, shelter, and height. Where indoor pressures are not uniform, more complex analyses are required.

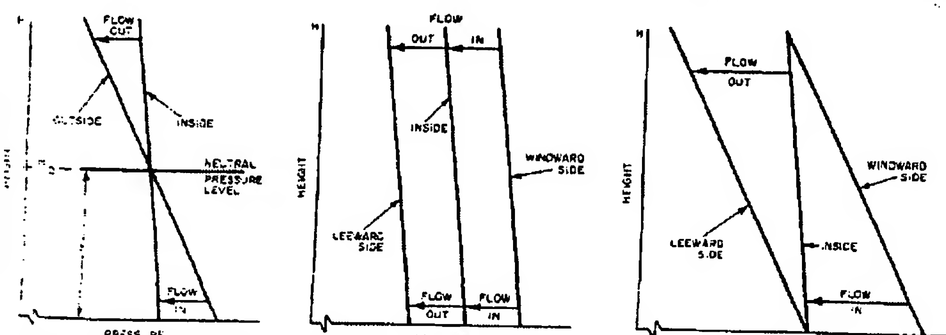
Neutral Pressure Level

The neutral pressure level (NPL) is that location or locations in the building envelope where there is no pressure difference. Internal partitions, stairwells, elevator shafts, utility ducts, chimneys, vents, operable windows, and mechanical supply and exhaust systems complicate the analysis of NPL location. An opening with a large area relative to the total building leakage causes the NPL to shift toward the location of the opening. In particular, chimneys and openings at or above roof height raise the NPL in small buildings. Exhaust systems increase the height of the NPL; outdoor air supply systems lower it.

Figure 5 qualitatively shows the addition of driving forces for a building with uniform openings above and below mid-height and without significant internal resistance to airflow. The slopes of the pressure lines are a function of the densities of the indoor and outdoor air. In Figure 5A, with inside air warmer than outside and pressure differences caused solely by thermal forces, the NPL is at mid-height, with inflow through lower openings and outflow through higher openings. Direction of flow is always from the higher to the lower pressure region.

Figure 5B presents qualitative uniform pressure differences caused by wind alone, with opposing effects on the windward and leeward sides. When the temperature difference and wind effects both exist, the pressures due to each are added together to determine the total pressure difference across the building envelope. In Figure 5B, there is no NPL because no locations on the building envelope have zero pressure difference. Figure 5C shows the combination, where the wind force of Figure 5B has just balanced the thermal force of Figure 5A, causing no pressure difference at the top windward or bottom leeward side.

The relative importance of the wind and stack pressures in a building depends on building height, internal resistance to vertical airflow, location and flow resistance characteristics of envelope openings, local terrain, and the immediate shielding of the building. The taller the building is and the smaller its internal resistance to airflow, the stronger the stack effect. The more exposed a building is, the more susceptible it is to wind. For any building, there are ranges of wind speed and temperature difference for which the building's



A. STACK ACTION ONLY WITH NEUTRAL PRESSURE LEVEL AT MID-HEIGHT B. WIND ACTION ONLY WITH PRESSURES OF EQUAL MAGNITUDE ON WINDWARD AND LEEWARD SIDES C. WIND AND STACK ACTION COMBINED

Fig. 5 Distribution of Inside and Outside Pressures over Height of Building

88

infiltration is dominated by the stack effect, the wind, or the driving pressures of both (Sinden 1978a). These building and terrain factors determine, for specific values of temperature difference and wind speed, in which regime the building's infiltration lies.

The effect of mechanical ventilation on envelope pressure differences is more complex and depends on both the direction of the ventilation flow (exhaust or supply) and the differences in these ventilation flows among the zones of the building. If mechanically supplied outdoor air is provided uniformly to each story, the change in the exterior wall pressure difference pattern is uniform. With a nonuniform supply of outdoor air (for example, to one story only), the extent of pressurization varies from story to story and depends on the internal airflow resistance. Pressurizing all levels uniformly has little effect on the pressure differences across floors and vertical shaft enclosures, but pressurizing individual stories increases the pressure drop across these internal separations. Pressurizing the ground level is often used in tall buildings to reduce stack pressures across entries.

Available data on the NPL in various kinds of buildings are limited. The NPL in tall buildings varies from 0.3 to 0.7 of total building height (Tamura and Wilson 1966, 1967a). For houses, especially houses with chimneys, the NPL is usually above mid-height. Operating a combustion heat source with a flue raises the NPL further, sometimes above the ceiling (Shaw and Brown 1982).

Thermal Draft Coefficient

Compartmentation of a building also affects the NPL location. Equation (17) provides a maximum stack pressure difference, given no internal airflow resistance. The sum of the pressure differences across the exterior wall at the bottom and at the top of the building, as calculated by these equations, equals the total theoretical draft for the building. The sum of the actual top and bottom pressure differences, divided by the total theoretical draft pressure difference, equals the **thermal draft coefficient**. The value of the thermal draft coefficient depends on the airflow resistance of the exterior walls relative to the airflow resistance between floors. For a building without internal partitions, the total theoretical draft is achieved across the exterior walls (Figure 6A), and the thermal draft coefficient equals 1. In a building with airtight separations at each floor, each story acts independently, its own stack effect being unaffected by that of any other floor (Figure 6B). The theoretical draft is minimized in this case, and each story has an NPL.

Real multistory buildings are neither open inside (Figure 6A), nor airtight between stories (Figure 6B). Vertical air passages, stairwells, elevators, and other service shafts allow airflow between floors. Figure 6C represents a heated building with uniform openings in the exterior wall, through each floor, and into the vertical shaft at each story. Between floors, the slope of the line representing the inside pressure is the same as that shown in Figure 6A, and the discontinuity at each floor (Figure 6B) represents the pressure difference across it. Some of the pressure difference maintains flow through openings in the floors and vertical shafts. As a result, the pressure difference across the exterior wall at any level is less than it would be with no internal flow resistance.

Maintaining airtightness between floors and from floors to vertical shafts is a means of controlling indoor-outdoor pressure differences due to the stack effect and therefore infiltration. Good separation is also conducive to the proper operation of mechanical ventilation and smoke management systems. However, care is needed to avoid pressure differences that could prevent door opening in an emergency. Tamura and Wilson (1967b) showed that when vertical shaft leakage is at least two times the envelope leakage, the thermal draft coefficient is almost one and the effect of compartmentation is negligible. Measurements of pressure differences in three tall office buildings by Tamura and Wilson (1967a) indicated that the thermal draft coefficient ranged from 0.8 to 0.9 with the ventilation systems off.

COMMERCIAL AND INSTITUTIONAL VENTILATION REQUIREMENTS

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ASHRAE *Standard* 62.1 contains requirements on ventilation and indoor air quality for commercial, institutional, and high-rise residential buildings. These requirements address system and equipment issues, design ventilation rates, commissioning and systems start-up, and operations and maintenance. The design requirements, include two alternative procedures:

- The prescriptive **ventilation rate procedure** contains a table of outdoor air ventilation requirements for a variety of space types with adjustments for air distribution in rooms and systems serving multiple spaces. These minimum outside air ventilation rates are based, in part, on research by Berg-Munch et al. (1986), Cain et al. (1983), Iwashita et al. (1989), and Yaglou et al. (1936) as well as years of experience of designers and building operators.
- The **indoor air quality procedure**, which achieves acceptable indoor air quality through the control of indoor contaminant concentrations. Such control can be realized through source control,

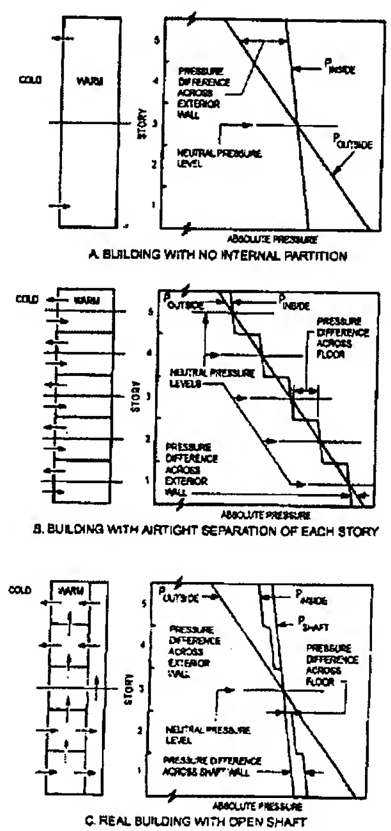

Fig. 6 Compartmentation Effect in Buildings

89

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